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<th>Emerging new product development methodology for the automobile industry</th>
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<tr>
<td>Author(s)</td>
<td>Thoma, Benjamin</td>
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<tr>
<td>Publication Date</td>
<td>2014-07-21</td>
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<tr>
<td>Item record</td>
<td><a href="http://hdl.handle.net/10379/4517">http://hdl.handle.net/10379/4517</a></td>
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Emerging New Product Development Methodology for the Automobile Industry

Case Study of Chinese and German Automobile Industries

In One Volume

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Doctor of Philosophy

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Final submission: July 2014
Abstract:

New competitive pressures are unsettling traditional carmakers. These include: new consumer groups in emerging markets; zero emission requirements of existing customers; new competitors from emerging markets; and increasing dependency on suppliers. These pressures require carmakers to react more rapidly while designing new models of automobile. New product development (NPD) is the core process used to develop synergy between customer requirements and the objectives of the carmakers to produce successful automobiles. NPD has served carmakers well during an era of relatively stable competition with easily recognizable technologies and competitors. In a new area, where technologies are changing rapidly and new competition is emerging, there is a need for a new approach to NPD. In this research, the author reviews existing innovation patterns of both traditional and emerging carmakers. This analysis has led to the development of an emerging NPD methodology that consists of concept, design and validation phases highlighting the interfaces to key stakeholders (such as consumers, infrastructure providers, suppliers, etc.). The emerging NPD methodology is informed and validated through a case study based approach focusing on Chinese and German automobile industries that shows how emerging market players disrupt the concept phase, whereas global OEMs adapt the design phase while trying to comply with emerging automotive trends. A cornerstone of the emerging NPD method is the demand for zero emission. This is demonstrated via new business models, whereas overall competitiveness is achieved through stakeholder integration facilitated by social networks. The findings of the research are confirmed by empirical research. The author concludes by giving recommendations based on the emerging NPD methodology and its associated NPD toolbox that allows carmakers to better cope with changing requirements in the automotive sector.

Key words — disruptive innovation patterns, emerging markets, zero emission vehicles, automotive NPD, Chinese car industry
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List of Abbreviations

ACEA – European Automobile Manufacturer’s Association
BAIC – Beijing Automobile Industry Corporation
BIW – Body in White
BJ – Beijing
BRIC – Brazil, Russia, India, China
BYD – Build Your Dreams (Chinese OEM)
CAD – computer assisted design
CE - Concurrent Engineering
CKD – Complete-knocked down (kit)
CNPC – China National Petroleum Corporation
CNG – compressed natural gas
CO2 – Carbon Dioxide
CRM – Customer Relationship Management
DFx - Design for Assembly/Manufacturing/etc
E/E – Electric/Electronics
ETS – European Transfer System
EUCAR – European Council for Automotive Research
EV – Electric Vehicle
FAW – First Auto Works (Changchun)
FAW-VW – First Auto Works-Volkswagen
FC – fuel cell
FMEA - Failure mode and effects analysis
GM – General Motors
HEV – hybrid electric vehicle
HQ – Headquarter
ICE – Internal Combustion Engine

IDEF0 – Icam DEFinition for Function Modeling, where 'ICAM' is an acronym for Integrated Computer Aided Manufacturing

IEEE – Institute of Electrical and Electronics Engineers

IP – Intellectual Property

IT - Information Technology

JIT - Just In Time

JV - Joint Venture

LCOE – Levelized cost of electricity

LPDS - Lean Product Development System

MNC – Multinational Corporation

MOST – Ministry of Science and Technology

NDRC – National Development and Reform Commission

NPD – New Product Development

OEM – Original Equipment Manufacturer

OES – Original Equipment Supplier

PATAFC – Pan Asia Technical Automotive Center

PHEV – plug-in hybrid electric vehicle

PPAP - Product Parts Approval Process

PPP – public private partnership

QFD - Quality Function Deployment

R&D – Research & Development

RMB – remimbi (Chinese Yuan)

SAIC – Shanghai Automobile Industry Corporation

SPC - Statistical Process Control

SOE – State-owned Enterprise

SVW – Shanghai Volkswagen
TQM - Total Quality Management
US – United States
VOC - Voice of the Customer
VW – Volkswagen
WTO – World Trade Organization
Declaration

The author hereby declares that, except where duly acknowledged, this thesis is entirely his own work and has not been submitted for any degree in the National University of Ireland, or in any other University on the basis of any of this work.
Papers published from this research

Journal Papers


Conference Papers


Acknowledgements

Many people have contributed to the development of this research thesis. In particular, I wish to acknowledge the contribution of Dr. David O'Sullivan, not only for his support and guidance over the past five years, but also for his suggestions and ideas in relation to this research. I would also like to thank him for his availability and the liberty he granted me throughout the entire course of this project. His valuable advice in several discussions helped me to make this project a success.

Special thanks to all those who were willing to take part in the expert interviews that were critical to validate the findings presented in this research. I am grateful to all of them, too many to mention individually, with whom I have discussed and refined the initial ideas developed in this research. I have learnt the most from the interactions we have had, as it allowed me to improve and validate my findings. Special thanks to Dr. Michael Schinkel (Vice President Strategy & Business Development at Daimler Northeast Asia), who has continuously encouraged me to continue my research and acted as my sparring partner on many ideas.

In addition, I would like to express my gratitude for my mentor Dr. Joseph Herold, who supported me throughout all my studies in making the right decisions. Last but not least, I would like to thank Dr. Martin Bloedt and Mrs. Kuangshen Gu for proof-reading the manuscript.

My deepest gratitude is to my family – my wife Carsyn and our daughter Atia. With unhesitating faith and support they encouraged me to pursue my thesis project. Cordial thanks for your love and understanding during my time conducting this research.
Dedication

This is dedicated to my wife and daughter for all their help and support over the years.

"Qui agit intellegit": Through Action comes Understanding
CHAPTER 1 INTRODUCTION

1.1 INTRODUCTION

This research provides a review of existing innovation patterns of both traditional and emerging carmakers. This analysis has led to the development of an emerging NPD methodology from the author’s research over the past five years consisting of concept, design and validation phases highlighting the interfaces to key stakeholders to the NPD activity. The new methodology is informed and validated through a case study based approach that shows how emerging market players disrupt the concept phase, when global OEMs adapt the design phase by trying to comply with emerging automotive trends. A cornerstone of the emerging NPD method is the demand for zero emission. This is demonstrated via new business models, when overall competitiveness is achieved through stakeholder integration facilitated by social networks. The findings of the research are confirmed by empirical research based on a total of 48 expert interviews with focus on Chinese and German automobile industries. Action research leverages the experience of the author in addition to the expert interviews. The author concludes by giving recommendations based on the emerging NPD methodology and its associated NPD toolbox that allows carmakers to better cope with changing requirements in the automotive sector.

1.2 MOTIVATION

The competitive environment in the automotive industry is unsettling traditional players. After the invention of the first automobile, patented by Karl Friedrich Benz in 1886, and Henry Ford’s mass assembly of vehicles in the first quarter of the 20th century, followed by Toyota’s lean manufacturing revolution after the Second World War, the automotive industry has been characterized by the so-called triad markets namely,
North America, Europe and Japan. Car makers from these regions have dominated global car markets, which have designed vehicle products that suit primarily the consumer preferences in these regions. The predominant powertrain technology has remained unchanged, apart from incremental product innovations, for over a century, based on the internal combustion engine (ICE) principle (In a motor vehicle, the term powertrain describes the main components that generate power and deliver it to the road surface. This includes the engine, transmission, drive shafts, differentials, and the final drive). While average travel speeds of automobiles in urban areas have not increased significantly, the growth of car density per capita has made the automobile a pillar innovation impacting most people’s lives in the developed world. Recent emerging trends however, are now unsettling this traditional paradigm as all aspects of competitive environment are undergoing changes that require car makers to re-think their existing model of operation. Using Porter’s five forces analysis as a framework [104], four external drivers are creating unrest within the automotive industry in addition to ongoing rivalry among existing firms.

Fig. 1-1 Analysis of emerging trends in the automotive industry
The rise of new consumer groups in emerging markets, most particularly in China, require vehicle manufacturers to develop new vehicle products suiting their distinct needs. China has become the no. 1 vehicle market in the world and gained significant importance versus the triad markets (US, Western Europe and Japan) as depicted in the following figure.

![Evolution of vehicle sales](image)

**Fig. 1-2 Evolution of vehicle sales [million units] [71], [72]**

The future in automotive industry is around cars and systems that are closely tailored to the demand for low cost and can remain flexible enough to allow upgrades and personalization [72]. R&D is to take place close to the market and local R&D centers will be connected by strong as well as flexible networks. Partnerships are crucial in providing timely access to new technologies, markets and business models. The further shift of sales and production to BRIC markets and in particular China is creating new lead markets. As shown in the previous figure, new vehicle sales (and also production) will shift from triad markets to emerging markets, particularly to China, which is already today the no. 1 vehicle market.

At the same time, substitutes for existing propulsion technologies such as electric vehicle drives and its derivatives have become the paramount innovation in the fast changing automotive world. The following
table depicts the evolution of new energy vehicle market shares in key markets around the world based on a ‘Low’ and ‘High’ scenario.

Table 1-1 Evolution of new energy vehicle market shares [16], [72]

<table>
<thead>
<tr>
<th>NEV market share [%]</th>
<th>2015 Low</th>
<th>2015 High</th>
<th>2020 Low</th>
<th>2020 High</th>
</tr>
</thead>
<tbody>
<tr>
<td>EU</td>
<td>1.6</td>
<td>3.1</td>
<td>5.8</td>
<td>19.6</td>
</tr>
<tr>
<td>US</td>
<td>0.3</td>
<td>0.6</td>
<td>1.5</td>
<td>12.5</td>
</tr>
<tr>
<td>Japan</td>
<td>0.2</td>
<td>0.4</td>
<td>1.1</td>
<td>8.1</td>
</tr>
<tr>
<td>China</td>
<td>0.2</td>
<td>3.8</td>
<td>1.8</td>
<td>15.8</td>
</tr>
</tbody>
</table>

The BRIC markets and to a large extreme China, also have different product requirements: while emissions and safety standards are likely to converge, customer requirements remain different. Already today, there is a higher share of low-budget solutions, but car functionality will also see different requirements. For example, at the 2011 Shanghai Motor Show, the first Chinese car was shown featuring speech/audio-enabled online navigation. This goes along with the fact that by 2025, nearly a quarter of all Chinese car drivers will be younger than thirty, and only around 10% will be older than sixty. On the other hand, only 6-7% of all drivers in Germany will be under thirty, while the share of elderly drivers (sixty years old or over) will increase to over a third of all drivers. These distinct groups have completely different requirements regarding their vehicle functionality. As a consequence, China will therefore not only become more important from a sales and production perspectives, but will also become a lead market for new technologies. As centers of economic growth shift and demographics change, a new lead market or more will arise. These lead markets are characterized by increased competitive intensity, which leads to better designs and faster cost reduction. Consequently, this will put pressure on many global OEMs that need to shift the model of innovation.

New competitors arise in a world, where China has become the largest vehicle market globally driven by multiple factors. The following
The table shows the number of major automotive OEMs, a comparison between the United States and China. Today, there are almost as many players in China as there were in the early nineteen hundreds in the United States. China has become the source of new competitive players in the automotive industry. While today, their penetration in mature markets is next to non-existent, it can be foreseen that some change in the not far future.

Table 1-2: Evolution of number of major OEMs US vs. China

<table>
<thead>
<tr>
<th>No. of Major OEMs</th>
<th>~1900</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>US</td>
<td>48</td>
<td>3</td>
</tr>
<tr>
<td>China</td>
<td>None</td>
<td>46</td>
</tr>
</tbody>
</table>

Source: internet research

The assumption here is that car companies actively innovating and developing in the lead markets are more successful than those who try to innovate from the home market only. Basic technologies are usually available in all markets, but differentiated know-how is being generated only by applying these technologies in engineering and production and intervention with the end customer. Successful innovation therefore means not only innovation at the right time, but also in the right place – excel with a much higher regional and global complexity. Again, this implies a shift in the NPD approach of traditional OEMs.

Also, suppliers gain importance as they are able to provide complete key systems especially in the electric/electronics sector as depicted in the following picture.
Fig. 1-3 Evolution of E/E share per vehicle [73]

Today, there are only about 4 key suppliers in the electric/electronics (E/E) segment (Bosch, Delphi, Denso, Continental) that are taking larger and larger shares of complete system innovation in the E/E segment – a segment where OEMs have traditionally lagged behind in building in-house capabilities.

These forces or in other words, emerging competitive pressures will be analyzed in detail as a part of this research because they represent the motivation to propose and validate an emerging NPD methodology that allows traditional OEMs to cope with the above mentioned forces.

1.3 THEESIS SCOPE

The author has analyzed what has been first described by Goldman Sachs in 2003 [60] and later confirmed in 2010 [65]: the vast rise of BRIC countries is inevitable, taking a significant position in the world's GDP contribution. One of the pillar industries that both, contributes and profits from the rise, is the automotive industry. While looking at Chinese OEMs in particular, leapfrogging innovation by leveraging new propulsion technologies, namely electric vehicle (EV) drives has become a severe threat for mature global players [74]. Furthermore, through significant EV
roll-out in the coming years, the electric grid will not only experience new
load applications, but also a widely distributed energy storage system. EVs
could be one of the solutions in providing an opportunity for energy storage
if linked with smart grid functionalities [75]. As a result, this addresses
directly the intermittent power generation from renewables that could be
smoothened if such storage capability is widely available [17]. Renewables
intermittent power will get energy storage from EVs that allows less
weather dependent electricity markets and therefore being more efficient.
Simultaneously, true zero emission transportation from a well-to-wheel
perspective becomes feasible as renewables provide the power for EV
charging [14]. In summary, this would address more than 70% of the CO2
emission reduction potential while looking at power generation and
transportation industries combined [75]. Along with the emerging market
growth opportunities, this appears to be the ultimate way forward
addressing global needs in energy and transportation industries in a
sustainable manner.

The research outcome of this work has been developed based on two
key hypotheses that have been validated throughout the studies conducted:
Hypothesis 1. The Chinese automotive industry succeeds through disruptive
innovation patterns (e.g. EV technology leapfrog, low cost innovation, etc.)
leapfrogging their technology gaps; Hypotheses 2. The European and in
particular German automotive industry succeeds through their ability in
vehicle system integration (e.g. premium cars, perfection in technology
integration, etc.). The two hypotheses have originally been derived from the
following initial assumptions.

Initial assumptions leading to Hypothesis 1:

- China is the innovation leader in BRIC (based on R&D spending,
  patent applications and engineering graduates) [74]
- “The China Price” advantage plays a vital role to leapfrog
technology gaps allowing to offer innovation at low cost [24] [25]
• Local EV supply chain, government supportiveness and emerging consumer groups drive EV growth [16]

Initial assumptions leading to Hypothesis 2:
• Evolution of the car industry with key innovations from Germany
• Global success and innovations of premium car makers despite comparably low production volume
• Integrated approach to system development due to rigorous planning processes

In order to validate the two key hypotheses, a variety of initial assumptions had to be confirmed as shown in the following two chapters. This comprises technological developments in the mentioned fields such as EVs and renewables, market drivers covering regulatory environment, consumer behavior and so forth for China and traditional markets. Simultaneously, existing innovation patterns in these markets are analyzed. In addition, challenges arising from emerging technologies are outlined providing the motivation to find a novel approach that accommodates for these challenges as highlighted earlier on. The following figure depicts how these topics are interrelated and connected in the process of confirming initial assumptions and validating the hypotheses.

Fig. 1-4 Overview of the field of play
Assessing drivers, markets and technological trends consists of a combination of literature research and expert interviews. As a result, a market model, that has been developed, serves to illustrate the interdependencies of various influencing factors. In order to analyze existing innovation approaches, an emerging NPD approach serves as a consistent framework that allows comparisons along every stage of the process. Here, an IDEF0 model (see appendix for model description) helps for better illustration and appropriate nomenclature. Validations via expert interviews and case studies are a crucial element that confirms the findings of this research.

1.4 THESIS OBJECTIVES

Based on the given outline regarding this thesis motivation and scope covered, this section covers the objectives. Overall, this research has achieved the following goals:

1. An in-depth market assessment of the energy and transportation domains in both Europe and China. Deep-dive activities include the following (see Chapter 2 New Competitive Pressures in the Automobile Industry):
   a. Analysis of regulatory development and policies for climate change
   b. Consumer study on emerging consumer requirements
   c. Assessment of supply chain critical pathways (e.g. Li-ion batteries, electric motors, etc.)
   d. Macroeconomic analysis such as looking at the ‘China price’ or stimulus package effects

2. A review on innovation approaches in the context of transportation industry approaches such as (see Chapter 3 Research of Innovation Approached in the Automobile Industry):
a. Low cost car R&D approach  
b. Disruptive innovation pattern  
c. Vehicle system integration  
d. Comparative analysis of innovation approaches found in the transportation industry in both Europe (Germany focused) and China

3. Design and validation of an emerging NPD methodology for the automotive industry that is capable to coping with new competitive pressures (see Chapter 4 Validation of Research Results and Chapter 5 Emerging Automotive NPD Methodology):  
   a. Design of an emerging NPD methodology that expands from pure tank-to-wheel view to the entire chain from well-to-wheel  
   b. Derivation of an approach how to leverage disruptive and low cost innovation approaches when it comes to vehicle system integration via a NPD toolbox that feeds into the methodology  
   c. Validation of the emerging NPD framework for automotive OEMs that allows to enable both, the low cost system integration and optimization along well-to-wheel aiming at zero emission pathways

4. Provide illustration examples on how the methodology can be applied in practice (see Chapter 6 – Emerging Automotive NPD Methodology Applied):  
   a. An outline of potential challenges resulting from a higher portion of renewables in energy generation, while demonstrating the possibilities of the smart grid as an enabler for energy efficiency in the context of the electric vehicle revolution
b. Illustration how social networks can improve stakeholder integration in complex vehicle development projects coping with the new competitive pressures for traditional car makers

c. Analysis of the possibilities of electric-vehicles
d. Trends in low cost car development

By analyzing existing innovation approaches in the automotive industry in both, China and Europe, and designing and validating an emerging NPD methodology, it is expected to achieve the following:

1. Expansion from tank-to-wheel to well-to-wheel as part of the R&D framework of automotive OEMs and
2. Utilization of low cost innovation approaches as part of vehicle system integration.

The result from this is that an emerging approach for total system innovation is being derived expanding on both dimensions as illustrated in the following figure.

Fig. 1-5 Domain of novel approach of system innovation
1.5 THESIS STRUCTURE

Overall, the thesis is structured into seven chapters. Chapter 1 provides the introduction, motivation and background to the subject in order to highlight the overall context of the topic. Chapter 2 analyzes the new competitive pressures in the automotive industry that covers new consumer segments, zero emission requirements, emerging competitors and increasing dependency on suppliers. This then leads to Chapter 3, which examines the innovation approaches of both, traditional and emerging car makers. Chapter 4 details how the research results were validated illustrating the details on multiple expert interviews helping to confirm the models as presented in Chapter 5. Here, the author introduces an emerging methodology for the automobile industry that is able to cope with new competitive pressures. Chapter 6 illustrates a variety of examples on how the methodology can be used in practice and highlights different aspects of the NPD flow. Chapter 7 concludes this research by giving a summery and conclusion with directions for future research. The following figure shows the overall structure of the chapters.

![Thesis structure diagram](image)

**Fig. 1-6 Thesis structure**

1.6 CONCLUSION

New competitive pressures are paramount in the automobile industry and represent a challenge for traditional car makers from the triad markets.
The trend in the rise of BRIC markets, particularly in China give rise to strong new consumer groups with their distinct behaviors as well as new competitors that compete on different terms. Simultaneously, zero emission requirements push car makers to explore new technological boundaries. This brings another paradigm change for car makers. At the same time, suppliers of newly relevant key components (e.g. batteries for electric vehicles) are gaining power towards car makers as they are taking a large portion of the value chain. These pressures are analyzed in detail followed by researching innovation approaches of both, traditional and emerging car makers. As a result, the author proposes an emerging methodology for NPD. This methodology is then validated via a series of iterative expert interviews with focus on Chinese and German automobile industries. It is tested via a variety of case examples to illustrate the usage and applicability of the methodology. Action research leverages the experience of the author in addition to the expert interviews. The author concludes with the overall findings and provides an outlook and direction for future research in this field of research.
CHAPTER 2  NEW COMPETITIVE PRESSURES IN THE AUTOMOBILE INDUSTRY

2.1. INTRODUCTION

This chapter analyzes new competitive pressures in the automobile industry. It commences with a review of innovation in emerging markets by looking at various key indicators for innovation ranging from talent pool, patent applications to R&D investment. It then looks at the new competitive pressures in the automobile industry in detail. Commencing with new consumer segments, the research then covers zero emission requirements, emerging competitors and concludes with increasing dependency on suppliers.

2.2. INNOVATION IN EMERGING MARKETS

The following analysis consists of an overview of key indicators for innovation in BRIC countries. Relevant key indicators include talent pool, public-private R&D expenditure and no. of patent applications [28]. Simultaneously, a measure of the compound annual growth rate gives a trend indication over the period from 2000 through 2010. The European Innovation Scoreboard (EIS) [64] model for innovation is based on an input-output model and is used in this analysis for simplicity reasons. The following figure depicts the mentioned key indicators that are analyzed in the following for BRIC countries.
This brief analysis of R&D performance consists of talent pool, R&D expenditure and no. of patent applications. It provides an overview of the capability for automotive research and innovation in BRIC countries.

Commencing with talent pool, the research is a core prerequisite for innovation [28]. R&D funding can only realize its value when there is sufficient talent to turn knowledge into a source of growth. The following figure depicts an overview of no. of engineering and science graduates in BRIC countries.

Fig. 2-2 Overview of no. of science and engineering graduates in BRIC countries [‘000] – [74]
In Brazil, the number of engineering graduates grew by only 6% on average (CAGR) during the period from 2000 through 2010. Even though electrical/electronic engineers constitute the largest segment of engineering graduates, only about 5% of all engineering students.

In Russia, 35% of all graduates receive degrees in electrical/electronics engineering and IT. This gives indication of the potential of Russia's knowledge-based society, which is still in the process of transitioning from the former Soviet system to a market-based economy. It should be noted, however, that only 40% of engineering graduates actually work in their profession after they graduate [74].

India's engineering talent pool has risen steadily, with a cumulative average growth rate of 12% in the period from 2000 through 2010. Remarkably, about one-third of engineering graduates are in the field of IT, while a large portion of the remaining part are in traditional fields such as mechanical and civil engineering. Approximately 150 Fortune 500 companies operate offshore R&D centers in India – for example, Ford and Daimler in the auto industry, but also GE and Microsoft in other pillar industries [59].

In China, the number of engineering graduates rose to more than 2.8 million per annum in 2010. An interesting fact is that more than half graduated in fields related to electrical/electronic engineering & IT, according to the China Educational Statistics Yearbook.

In addition to the available talent pool that needs to execute the innovation process in public institutions or enterprises, the R&D fund allocation is crucial for a country's ability to come up with innovations. Therefore, government-set research targets that are defined in an R&D agenda play a key role in fostering relevant industry domains and boosting an industry's competitiveness according to the European Council for
Automotive Research (EUCAR) [9]. The following graph shows the trends in R&D fund allocation in BRIC countries.

![Graph showing R&D spending in BRIC countries (billion EUR)](image)

**Fig. 2-3** Overview of R&D spending in BRIC countries [billion EUR] – [74], [22]

India's total R&D spending as a percentage of GDP did not change significantly during the period 2000-2010, but remained at less than 1%. This is below the average in comparison to developed industrial nations. During the same time, India's GDP rose at a cumulative average growth rate of about 9%.

In China, R&D spending as a percentage of GDP rose from 0.8% to 1.5% of GDP in the period 2000 – 2010. During this same time, China's GDP experienced a compound annual growth rate of roughly 11%. China is preparing for indigenous innovation – including in such areas as alternative-powered vehicles. By comparison, R&D-to-GDP ratios in the US, Germany and Japan were 2.7%, 2.5% and 3.3% respectively in the year 2010 [64].
A result or output of the invested R&D funds and the talent pool that dominates the innovation work, number of patent applications is reflected as an outcome in the following analysis. While doing so, the national origins of patent holders need to be taken into consideration as some foreign companies could simply protect their IPR by filing patent applications in BRIC countries. The following graph compares the BRIC countries with respect to activity in the field of intellectual property.

Fig 2-4 Overview of number of patent applications in BRIC countries ['000] - [74], [59]

In Brazil, Petrobrás is the most active patent applicant. Petrobrás focuses mostly on chemicals and technology applicable to mineral exploration and extraction, and to the refining of oil, lubricants and fuel. This focus is very much in tune with Brazil's move toward ethanol-based automobile fuel.

Only 5% of Russia's patent applications relate to the auto industry, which only reflects the current bottom level of their automotive industry in terms of innovation.
In India, only about 18% of the patent applications in 2008 were of local origin. The majority rest originated in other countries, predominantly the United States, Germany, Japan and Switzerland. Roughly 9% of all patent applications are related to the auto industry [59].

In China, a large proportion of IT and electrical/electronic patents (37% in 2009) are held by companies with an international presence, such as Lenovo and Huawei. In other areas, public research institutions are the predominant patent holders. Universities have special departments dedicated to patents development. By contrast, Chinese companies – whether state-owned or private – rarely have the means or patience to conduct basic or applied research [59]. This situation is also seen in automotive companies, where designs are commonly brought in by foreign joint venture partners free of charge. The resulting framework for low-cost innovation in China will be analyzed later.

A concluding remark on this section, it is worthy to mention that China is the most innovative country of all BRIC countries while looking at the described indicators. Both CAGR and absolute figures for talent pool, R&D expenditure and patent applications are higher in China than in all other BRIC countries. This emphasizes the growing importance of China. It is also the reason why the following sections will focus in many areas primarily on China.

2.3. NEW CONSUMER SEGMENTS

In 2008, Tata introduced the cheapest car in the world, initially priced at $1,700, targeting India’s population that cannot otherwise afford a car. This is part of a new phenomenon of innovation from the so-called ‘bottom of the (customer) pyramid’ (BOP). The BOP market is characterized by people who live on less than $2/day [1] [2]. This equates roughly to four billion people worldwide and represents the largest
remaining global market frontier for businesses. These emerging consumer segments are the key driver for growth in developing markets [3]. To analyze the top of the pyramid, a whole new set of middle class customers is emerging with distinctive needs and tastes as a result of increasing urbanization in BRIC (Brazil, Russia, India, and China) countries.

China, in particular, is characterized by these market changes. Increasingly, Chinese people are leaving their rural environment to enter cities. They are searching for better living conditions by taking advantage of new employment opportunities fuelled by the industrialization of China’s East Coast. They find higher paying jobs in the rapidly expanding manufacturing and service sectors. Having taken the decision to build a new life in the city, these migrants have a high willingness to work hard and do their best to improve the lives of themselves and their families. Often they come to the cities debt free, so their first wage packet will have an immediate impact on their spending patterns. Along with the increased power to spend money comes the willingness to do so. The emerging consumer class is born [4]. The growing appetite for consumption has many faces. As consumers in the emerging middle class become wealthier – and are exposed to new ideas, new products and new markets – their tastes and preferences for goods and services are about to change. Literature research suggests the following classification of emerging market consumers:

Fig. 2-5 Emerging consumer framework in BRIC countries. [2], [4], Booz & Company, Nordea
The Early New Urban Consumer resembles neither the city dwellers they have joined nor the rural communities they have left behind. Their overall appetite tends to be strong for certain must-have items like basic food and beverages, as well as basic sanitary products.

As its disposable wealth grows the Developed New Urban Consumer shows a growing demand for discretionary products such as: personal care products, processed food, consumer electronics, household products (shampoo, toothpaste, dishwashing tablets, cosmetics etc.).

Mature Urban Consumers have gained a certain level of wealth and regular income which satisfies their needs for travelling (cars, holidays), education and security (insurances, protection of their property).

Luxury Consumers are a newly affluent cohort that wants Western badges of status to signal the arrival of prosperity. Owning luxury brands is the main goal. Here the motto is often “the higher priced, the better”.

Building on this consumer classification [1] [2] [4], the emerging automotive consumer in China can be described as follows: aged between 30 and 45, male, and uses the car equally for work-related and non-work-related travel. Most are private buyers that have generated wealth in recent years and live in coastal cities in the Eastern regions. Beyond this generic data, however, little is known about the demographics of Chinese car buyers. What is known though, is that the emerging automotive consumers in China are still very open while selecting their first vehicle. Typically, brand loyalty is very high in Western countries with around 80% of car owners considering the same brand for their new car. In China, on the other hand, brand loyalty levels are currently at 10% or lower. A major driving force for this is the fact that many consumers are still in the process of buying their first vehicle and therefore have no experience with brands. The used car market in China is just developing [4].
Focusing on the branding of cars in China, it is well known from mature markets that customers make their purchasing decision based on two ‘mega-attributes’: cost and vehicle excellence. In general, Chinese carmakers have commenced by positioning products in the volume market segment due to low cost positioning and lower average customer acceptance. Chinese carmakers, therefore, try to appeal on cost of ownership (neglecting life cycle considerations). This means that end consumers perceive such vehicles as good value purchases based only on cost. Meanwhile, traditional multinational OEMs have simply kept their typical brand attributes (e.g. Mercedes – luxury or Ford – affordable, etc.). Nevertheless, they too have recognized a variety of consumer preferences in the process of introducing vehicles in China: for example, different color schemes and materials in the vehicle interior, distinct vehicle model names, long wheel base, and etcetera. Furthermore, their typical market-relevant technical requirements are to be considered e.g. Chinese language navigation systems, local engine adaptation to suit the ‘bad’ fuel quality in China and so forth. In both cases being able to manage NPD that reflects the needs and tastes of new consumer groups are crucial for success in the market place.

2.4. ZERO EMISSION REQUIREMENTS

Commencing with an overview, world primary energy demand growth is described and discussed in the World Energy Outlook Reference Scenario. The Reference Scenario describes a future in which governments are assumed to make no changes to their existing policies and measures regarding the energy sector. The projections in this scenario are hence not a forecast of what will happen but rather a modeling of what would happen if there was no change in climate policy as it is expected that governments will make climate change their key priority in policy development. Though, looking at the Reference Scenario, energy demand would grow by 40% between 2009 and 2030, with coal recording the largest increase (+53%).
Non-hydro modern renewable energy technologies (including wind, solar, geothermal, tide and wave energy) would increase five-fold over the same period. Non-OECD countries would account for 93% of the increase in global demand between 2007 and 2030, driven largely by China and India. Consequently, world energy-related CO2 emissions in the Reference Scenario of the World Energy Outlook are set to rise by 40% by 2030 (given there are no new policies or measures). The effect of reduced energy demand due to the financial crisis on global trend would only be temporary. Even though, existing policies can stabilize CO2 emissions in OECD countries, the majority of the increase in CO2 emissions would be caused by new coal use outside OECD countries [5], [6].

The ‘IEA 450 Scenario’ analyses how global energy markets could evolve if countries take co-ordinated action to restrict the global temperature increase to 2°C [6]. This has been commonly acknowledged in the Copenhagen Accord. It assumes that the international community adopts the objective of stabilizing the long-term concentration of greenhouse gases at 450 ppm CO2 or in other words less than half the level reached in the Reference Scenario. OECD+ countries are assumed to take on national emissions-reduction commitments for 2020. All other countries are assumed to adopt domestic policies and measures, and to generate and sell emissions credits [5], [6]. After 2020, commitments are extended to other major economies, such as China, Russia and the Middle East region. In this scenario, global energy-related CO2 emissions peak just before 2020 at 30.9Gt and decline thereafter to 26.4Gt in 2030. In summary, efficiency measures will account for almost two-third of the abatement in 2020 and 2030 respectively (450 Scenario vs. Reference Scenario). While Renewables will contribute more than 20% in OECD+, substantial abatement potential exists outside the OECD+ region. Financing will become a key success factor to the energy sector meeting a 450 ppm trajectory [5].
Zero emission transportation is driven by the ongoing debate by policy makers around the world on climate change. On the one hand, a global viable mechanism to succeed the Kyoto protocol has yet to be found. However, the European Union has its climate and energy package with its 20-20-20 goals. The World Energy Outlook (WEO) analyses various scenarios on future usage of primary energy. As described before, the WEO refers to a Reference Scenario that describes a future in which governments are assumed to make no changes to their existing policies and measures regarding the energy sector. The projections in this scenario are, therefore, not a forecast of what will happen but rather a modeling of what would happen if there was no change in climate policy. It is generally accepted that governments will make climate change their key priority in policy development. Hence, it is no surprise that coal will remain the largest component of primary energy usage through to 2030. Non-OECD countries will account for the majority of increase in demand, driven largely by China and India [6].

Figure 2-6 shows a sectorial view of the WEO Reference Scenario and the Efficient World Scenario. The latter analyses how global energy markets could evolve if countries take co-ordinated action to restrict the global temperature increase to 2°C. [5].

![Fig. 2-6 Comparison of global CO2 emissions - Reference Scenario vs. Efficient World Scenario (Gt CO2)](image-url)
Traditionally, the transportation industry – and in particular the individual mobility industry – has been treated by sector specific requirements when it comes to emission reduction schemes. The efforts to reduce CO2 emissions from individual mobility are focused primarily on car technologies such as energy management, lightweight construction and aerodynamics. With such a technology-focused approach, most cost-effective CO2 reductions cannot always be achieved [8]. As this sector is excluded from Emission Trading System (ETS) and its equivalents around the world, few alternative options exist for the moment.

In the future, the effectiveness of technological measures on cars will increasingly depend on industry developments in areas outside the automotive industry – for example, the need for widespread availability of alternative fuels or the availability of an electric vehicle charging infrastructure [8]. The focus of the so-called Integrated Approach is not only on new car technology, but on all sources of CO2 emissions related to road transport.

The Integrated Approach envisages co-operation with key players whose concerted efforts in car technology, fuels, infrastructure, traffic management; and driver behavior would contribute significantly to higher CO2 emission reductions being achieved on a more cost-effective basis. This is a key element of the collaborative concept as outlined later in the case study examples of the novel NPD approach. Over time, changing consumer preferences have had a market impact on CO2 emissions. These preferences were shaped by demands for larger, safer, higher and roomier vehicles. In many countries these demands result from population shifts to rural areas that have created longer daily commutes to work or a general shift towards an increase in per capita car ownership (as seen in BRIC countries, for example). In addition, users demand cars that include the latest safety features, often adding more weight [9].
Significant CO2 reductions have been achieved despite increases in vehicle size, mass, power, and capacity that have been influenced by changing customer preferences. However, the 1998 self-commitment [7] of the European car industry could not be fully met. As a result, the European Commission and other policy makers around the globe have been or are in the process of installing legislative CO2 emission measures in close consultation with the car industry. In Europe, the New European Driving Cycle (NEDC) target is aimed at 130gCO2/km including further 10gCO2/km reductions via complementary measures. A bonus system for so-called eco-innovations incentivizes car innovations.

In contrast, the Chinese domestic automotive industry still lacks competitiveness in ICE technology [11]. Consequently, the government has neglected to establish short-term fuel efficiency targets that are not as strict as those found in the triad markets. The Chinese government is aware of the increasing importance of natural resources and its dependencies when it comes to importing resources for transportation purposes. This is evident from the increased the regulation on fuel consumption by an average of 10% for each weight class used in the Chinese emission type approval system in 2008. The emission requirements are still lagging behind Europe and other mature markets, but have been catching up quickly. As the fuel price in China is controlled by the state, oil companies do not have a strong interest in upgrading their refining facilities [11] – a prerequisite of being able to meet emission standards such as EUR 5 and more in the future. This lack of incentive to offer better fuel quality currently hinders the introduction of stricter emission regulations [12]. As automobile exports from China increase, the pressure to bring regulations into line with global standards will grow.

In both the European and China scenarios, the pressure on carmakers to push the roll-out of low-emission and eventually zero-emission vehicles is increasing. One pathway to zero-emission transportation is via electrification of powertrains [14] meaning to have a pure electric drive
eventually without the use of any ICE technology. This pathway begins with hybridization of conventional ICE technology eventually moving towards total electric drive. Another pathway to lower emissions (also combined with hybridization) is the use of alternative fuel types (e.g. bio fuels, CNG, etc.) which allows for an improved well-to-wheel emissions balance [13] [14]. Total electric drive provides the opportunity of bringing renewables into play and, therefore, allows for complete well-to-wheel zero emission pathways [14] [17]. Regardless of which pathway to lower transportation-related emissions prevails, it puts pressure on conventional ICE-focused carmakers. Suddenly they have to cope with the NPD of multiple propulsion technologies for their products.

2.5. EMERGING COMPETITORS

Emerging carmakers in China and India are now beginning to compete with the well-established ones from developed industrial nations. Recent years have shown a significant rise of vehicle sales in these countries and some indigenous carmakers have emerged (for example, Tata in India or BYD in China). While many still use conventional technologies, there is a push to enter global markets and to meet global standards and customer requirements. The consolidation and the merging of many small OEMs is now occurring and this will eventually lead to a few strong players who are able to compete on a global scale. This requires the capability to self-innovate. The following figure highlights the growth of BRIC markets over the past decade.
The automobile production in India has grown at a speed of ~10% cumulative average growth since 2002. The overall volume exceeds 10 million units with the number of passenger cars being only ~2 million units. This is still small comparing to China, but the potential is significant. Simultaneously, the Indian automobile industry has commenced to export to other countries. So far only Hyundai, Maruti, Ford and Tata have begun passenger car export with Hyundai accounting for roughly 50% of all exported vehicles. This can be explained by the fact that India is an integral part of Hyundai’s globalization plan and is an export hub for compact cars. The development of the Indian automobile industry dates back to the early 1950s. During the period from 1983-1993 when Suzuki was only one foreign entrant - via a joint venture, Maruti Suzuki. Since the early ‘90s as investment restrictions were loosened further, foreign OEMs started to build up their own manufacturing bases in India (e.g. GM, Daewoo, Volvo, Skoda, Daimler, Hyundai, Ford BMW, Volkswagen, Nissan, Renault, Hyundai). Unlike China, Indian foreign direct investments are automatically approved with no current investment minimum. Also, no joint venture (JV) policy exists, which is why most of the foreign players choose to own all operations. Only Ford, Renault-Nissan, Toyota and Honda operate within
JVs, with Renault-Nissan the only one that does not have a majority stake. Furthermore, there are no localization content minimums and no export obligations. Also, Indian auto parts manufacturers have reached quality levels required for export. The segment shares are still highly concentrated on traditional or conventional auto components with a high level of mechanical parts. While looking at the research activities in the automotive arena, the public-private partnerships – such as the Core Group on Automotive R&D (CAR) and the Automotive Research Association of India (ARAI) – gather domestic and global players to conduct research on future technologies (e.g. European funded FP7 project SIMBA). Some specific items that have emerged from research are bio-fuels extracted from the oil in seeds of the Jatropha plant as well as Hydrogen/CNG blends that make better use of this precious energy carrier with conventional combustion technologies. These so-called H-CNG blends can be used in modified CNG vehicles to further reduce emissions.

Having experienced double digit growth since the opening of the Chinese market, automotive sales and production have surpassed all other markets in the world. With foreign players present for more than 30 years (VW and Chrysler being the first to enter in 1985 and 1983 respectively [12]), many requirements exist to make China different from other BRIC markets. For example, foreign OEMs can only produce vehicles as part of a JV operation of which they cannot own a majority stake (maximum 50%). Imported vehicles whether completely built-up (CBU) or knocked-down (CKD) are subject to a ~25% import tariff. CBU refers to vehicle importants of complete vehicles, while CKD refers to importuning car kits that are then assembled locally. If the requirements of the automotive industry policy, which demands to localize key systems meeting at least 40% local content, are met, the import tariff for the remaining parts that are still imported is reduced to ~10%. While these requirements are loosened, they still exist indirectly and drive foreign players to invest in local supplier development, which provide parts to their local production facilities [18] [19]. VW in particular has benefited greatly from its two JVs with FAW and SAIC and
continues to lead the market. The growth of local players is also beginning to unleash the potential in research. Local OEMs originally organized only in state-owned enterprises (SOEs) – such as SAIC, FAW, BAIC – that gain technology transfer via Sino-foreign JV operations or, as recently experienced, foreign acquisitions include also purely private players (Geely, Cherry, BYD for example). While looking at motor shows in China IPR infringements are still present. Until 1980, knowledge or inventions were transferred without charge from academia to state-owned companies. Universities and research institutions were solely responsible for R&D and provided their results to manufacturing industry. Nevertheless, public research programs – such as the 863 program – initiated by the Ministry of Science and Technology (MOST), as well as incentive policies, have given rise to the development of new energy vehicles. The most prominent is BYD which intends to revolutionize the car industry with electric vehicles. This is only one example besides the fact that China plays a leading role in lithium-ion battery market – a key part of electrified powertrains – being second worldwide with a 22% market share after Japan.

In summary, emerging players from China and India are creating a potential threat to triad players (car makers from the US, Europe and Japan) as they learn to innovate in their own way. Simultaneously, triad OEMs are forced to adopt their NPD approach if they want to penetrate emerging markets via localization and local product adaptation.

For reasons of completeness, the author also highlights the situation in both Brazil and Russia. Brazil is without local OEMs, but still hosts local automotive engineering operations. In summary, the market totally depends on foreign players who operate local production facilities for both, local distribution and export. This includes both vehicle and engine manufacturing and assembly with some localization of parts, but without any policy requirements imposed by the government. VW is the biggest producer of passenger cars in Brazil, whereas Fiat has the highest domestic sales. Some OEMs such as Daimler concentrate their efforts on local
production for export only. Bio-ethanol for transportation fueling is the key technological trend for car players in Brazil. During seventies, the Brazilian government decided to diminish dependence of oil by investing in technologies based on bio-ethanol. This policy shows its effect in the amount of refineries for bio-fuels, which have emerged during recent years (despite Brazil’s vast amount of hydrocarbon resources exploited by Petrobras) boosted by public and private funding. A viable technical solution for cars has only been introduced in 2003 by VW launching the first commercial flex-fuel vehicle. Since then, almost every model introduced by VW was flex-fuel based. Fiat developed the Siena Tetra flex-fuel car together with Magnetti Marelli, which runs 100% gasoline or 100% bio-ethanol, with any mixture of bio-ethanol and gasoline and 100% natural gas – depending on the user’s choice.

In Russia, foreign players have entered Russia for local assembling activities between 2001-2008 (VW, Toyota, Ford, Hyundai, GM). They mainly consist of CKD plants as critical mass to localize has not yet been reached. Taking into account, that 80-85% of all components are being consumed by local producers, global OEMs have no choice but concentrating on local assembly only. Global players R&D activities remain outside Russia with little transfer of technologies to Russia's plants. Exception is GM with Chevy Niva, which is a product that resulted from combined efforts with AvtoVAZ R&D activities. Also, some global players have research monitoring offices in Moscow to monitor any uprising trends. Local players are still operating with about 75% of the value chain in-house. Local players are AvtoVAZ, GAZ and Sollers for example. In total, locally produced vehicles had a market share of 53% in 2008 – hence, reflecting that Russia is a big market for importers with relatively much less activity local. This has not always been the case – as during the Soviet government, local OEMs enjoyed a monopoly. Since the early 90' this situation is changing leaving local OEMs behind. Today they still have outdated products and manufacturing techniques that keep up to 75% of the value chain in-house. New entrants from China and India with low cost cars make
it hard to compete for local OEMs in this segment. Today, there are roughly 250 cars per thousand inhabitants in Russia with further potential growth. In summary, both Brazil and Russia are less relevant when it comes to emerging competition in the automotive industry. The following figure highlights the contribution of vehicle sales from BRIC countries over the past decade illustrating the importance of China.

Fig. 2-8 Breakdown of contribution of vehicle sales by BRIC country over the past decade (in million units) [105]

2.6. INCREASING DEPENDENCY ON SUPPLIERS

There is a clear trend towards electrification of powertrains or in other words towards various forms of hybrid electric vehicles (HEVs) and electric vehicles (EVs). The following figure shows an overview of this trend disregarding fuel types for simplicity reasons [15].

Fig. 2-9 Trends in electrification of powertrains
In addition to the policy trends aiming at CO2 emission reduction, consumer requirements will have a significant impact on EV roll-out. A key question for automakers is that whether consumers will accept a limited driving range and a poor recharging infrastructure? Three key components are vital to EV success: (i) Power electronics; (ii) Electric motors; and (iii) Battery storage [15].

Power electronics are critical for energy management in any electric vehicle type whether hybrid electric or pure electric. It requires the core skill of understanding the entire vehicle architecture as well as the capability to design key components that can manage high energy loads. Electric motors on the other hand have been around for a long time but have not been widely used in automotive applications. Tier 1 suppliers are in process of designing and manufacturing such electric motors for wide usage in automotive applications. Battery storage, which is the key cost driver for EVs, represents more than twice the cost of both power electronics and electric motors combined. At present, the majority of battery suppliers are focused on Li-Ion battery technology. It is likely that this technology will dominate the production ramp-up phase for the coming five to ten years. Although a number of alternative composite materials exist for the anode, cathode and electrolyte of battery cells, all suppliers will need a certain amount of lithium based raw material. As a result, batteries for EV applications will be the main driver for an increasing demand of lithium. Lithium carbonate reserves (three-quarter of global reserves being found in Latin America) are currently sufficient and are not expected lead to shortages on the supply side. There is a risk of temporary price increases as experienced in recent years. As technological development progresses along with economies of scales, it is expected that battery costs will fall threefold between now and 2020 [16].

Looking at EV charging options, there are three levels of charging: Level 1 – referred to as slow charging - with 230VAC, 15A, compatible
with the most commonly available grounded electrical outlets applicable as emergency charging option with a typical charging time of 15-20+ hours. The charging times are based on a Nissan Leaf case example with a 5kWh battery and a 160km driving range. Level 2 – referred to as faster charging – has 230VAC, up to 80A and results in a typical charging time of 4-8 hours. This is the typical charging option for homes, offices, parking lots and public facilities. Technical solutions are in the commercial phase from various manufacturers. Level 3 – referred to as super-fast charging – has 3 phases 480VAC for commercial applications applicable like a gas station with charging times of 15-30 minutes only.

After the analysis of technological trends vital to the success of EVs, the following reviews the market potential. Recent studies have shown that by 2020 there will be an average penetration in percentage of new vehicles sales of around 5% for EVs and around 10% for plug-in HEVs (PHEVs) in the triad markets and China. With mild hybrid and micro hybrid in this consideration included, penetration rates above 95% are forecasted. For Europe that would translate in 2020 into roughly 3.5 million vehicles with purely electric driving capability (EV and PHEV) sold [11].

Conservative assumptions are that for every electric powered vehicle sold, 2.5 charging stations need to be built, based on the assumption that one EV needs at least one residential charger, a workplace charger, and a smattering of commercial chargers. This also assumes that EVs will have to be charged were they sit for long periods every day. At the same time, such additional electric loads require new capabilities of grid applications integrating the electrical infrastructure along with an information infrastructure. Essentially this offers new opportunities for utilities and grid operators/service providers by charging a premium for electricity and related services including payment procedures and so forth.

The implications and opportunities of the described paradigm change resulting from a larger portion of Renewables, but also the EV
revolution are addressed in the Appendix. Traditionally, the core competency of a car maker was to develop world class ICE-based, propulsion technologies and design and manufacture vehicles to suit consumer tastes and that complied with regulatory requirements. The implications of this paradigm change for both, drive train technology and infrastructure needs, make traditional OEMs increasingly dependent on suppliers. Today, only four Tier-1 electric/electronic (E/E) suppliers exist and these are taking an increasing share of the carmaker’s value chain. In other words, batteries and other E/E modules are becoming key components of vehicles and its value chain might no longer be part of the core competency of the OEM. At the same time, road infrastructure and transportation system providers tackle the downstream end of the chain with new solutions harmonizing the use of alternative propulsion systems within existing environments. The following table summarizes the key takeaways from this section illustrating the increasing dependency on suppliers as a result of the technology shift.

Table 2-1 Overview of key takeaways regarding increasing dependency on suppliers due to technology shift

| Powertrain technology experiences electrification as a result of the shift towards electric drives |
| This drives the need for new key components: (i) Power electronics; (ii) Electric motors; and (iii) Battery storage. Batteries are the most costly (and limiting) components of the three |
| Charging the batteries remains a key challenge for the car industry as it takes much longer compared to fueling a vehicle conventionally and hence creates an unfavorable consumer experience |
| Electric vehicles drive the need for a tremendous charging infrastructure that does not exist today |
| Additional electric loads from charging electric vehicles creates a challenge for the electric grid |
| Type of energy source utilized to generate electricity will become the main driver for emissions in road transportation |
2.7. CONCLUSION

This chapter that commenced by analyzing key factors provides an indication on innovation maturity in BRIC countries. Firstly, talent pool of scientists and engineers were analyzed along with a study of investment and annual growth in both public and private R&D funds including indication of origin of funds. Both factors coupled would naturally result in new product development innovations in the respective countries. A way to analyze that was a study of new patent applications in the respective countries. The overall result is that both from an absolute and growth perspective, China dominates the BRIC countries from all others, which is why this thesis has a strong focus on the China new product development mechanisms. Consequently, new competitive pressures in the automotive industry were analyzed. As a new consumer segment, the middle class has risen great importance in emerging markets, which was studied to highlight distinct consumer preferences in automotive different from traditional markets. Zero emission requirements is another driver putting pressure on traditional car makers requiring them to innovate their conventional propulsion technologies and hence breaking open a sector with traditionally high entry barriers. Last but not least, new powertrain technologies give rise to suppliers taking a larger and larger portion of the car maker’s value chain by supplying complete systems especially in the electric and electronic sector. In summary, the analyzed competitive pressures provide a rationale for car makers to employ emerging approaches to new product development in order to remain competitive in the market as shown in the following chapters.
CHAPTER 3 RESEARCH OF INNOVATION APPROACHES IN THE AUTOMOBILE INDUSTRY

3.1. INTRODUCTION

This chapter provides an overview and analyses of NPD approaches in the automotive industry. It commences with a review of common practices and how NPD evolved over the past decades. Here, Cooper’s stage gate methodology, but also the contrasting concurrent engineering principles are introduced. Then, the author provides his analysis of how emerging players employ indigenous NPD models. This is a critical research in order to developing a toolbox for OEMs to coping with new competitive pressures in the automotive industry. Furthermore, the author then highlights how traditional OEMs are coping with increasing pressures, both from emerging markets as well as emission requirements. In addition, the author provides a framework for traditional OEMs to cope with emerging market requirements. This is another important milestone in developing a set of tools for OEMs to coping with new competitive pressures that will later be used as part of the emerging NPD methodology. Moreover, these overviews are critical in order to propose and refine an emerging NPD model capable of coping with emerging requirements. In summary, this section introduces a variety of tools that enable manufacturers to better cope with new competitive pressures in the automotive industry.
3.2. BACKGROUND ON NEW PRODUCT DEVELOPMENT

Having assessed in relevant detail how emerging trends in the automotive industry are unsettling traditional players, this section outlines identified approaches to innovation. After a century of new product development, the first formal approach utilized in the automotive industry is value engineering. This was a method to reduce the cost of existing products and was developed during the Second World War by General Electric [68]. It remains today a common tool in the automotive industry. Henry Ford introduced the concept of mass manufacturing in the early 1930s and Alfred P. Sloan’s pioneered the setting up of a corporation with multiple brands, tailoring vehicles to various customer needs, just prior to WWII [80]. His way to managing a large industrial corporation has been researched by Peter F. Drucker, who as a result of his study on General Motors, first published about management as a discipline and function [81].

William Edwards Deming was an American engineer, statistician, professor, author, lecturer, and management consultant who first implemented Statistical Process Control. He is best known for his work in Japan after WWII, particularly his work with the leaders of Japanese industry which began in August 1950 at the Hakone Convention Center in Tokyo with a now seminal speech on what he called Statistical Product Quality Administration, which many in Japan credit with being the inspiration for what has become known as the Japanese post-war economic miracle of 1950 to 1960, rising from the ashes of war to become the second most powerful economy in the world in less than a decade, founded on the ideas first taught to them by Dr. Deming [106]:

1. That the problems facing manufacturers can be solved through cooperation, despite differences.
2. Marketing is not "sales," but the science of knowing what people who buy your product repeatedly think of that product and whether they will buy it again, and why.
3. That in the initial stages of design, you must conduct market research, applying statistical techniques for experimental and planning and inspection of samples.

4. And you must perfect the manufacturing process.

While these ideas were a critical inspiration for Japanese car makers, the next major development was the introduction of lean manufacturing by Toyota in the late 1980s, made possible through a $5 million MIT study on the subject [67]. This was one of the largest and most thorough research study ever undertaken of any industry: MIT's five-year, fourteen-country International Motor Vehicle Study. “The Machine That Changed the World” describes the story of lean production, Toyota's secret weapon in the global car wars that has been revolutionizing the world industry. When “The Machine That Changed the World” was first published in 1990, Toyota was half the size of General Motors. Today, Toyota has passed GM as the world's largest auto maker and is the most consistently successful global automobile enterprise of the past fifty years. Toyota's lean production system contrasts two fundamentally different business systems: lean versus mass; two very different ways of thinking about how humans work together to create value. Today, lean principles have been widely adopted by the automobile industry even going beyond just manufacturing but touching the entire value chain. Also, other industries from healthcare to retail have adopted lean principles in their organization.

Toyota’s lean principles have been applied to new product development and intensively studied over the past decade [82], [83], [84]. The Toyota system allows developing products in much less time with many fewer hours of engineering, products that cost much less to manufacture and that have many fewer defects as reported by customers (these products are also sold at considerably higher prices within a given segment of the auto market). This product development system consistently creates more value with less time and effort, which is the very definition of lean. Overall, the Toyota method comprises the chief engineer principle or
in other words programs management, set-based concurrent engineering [85], the front loaded development process, leveled process flow, design for assembly, and design for manufacturing, value stream mapping, and continuous improvement, rigors standardization of design, process and engineering skill [90]. It also reveals the power of Quality Function Deployment (QFD) in NPD [88], [89] as well as supplier integration into NPD [86], [87], [91]. In summary, it consists of a set of tools and principles that make up the so-called Lean Product Development System (LPDS). The system describes a set of tools that spans along the organizational set-up, of which many have become a widely used practice in the automotive industry, while not all of these can be directly linked to be invented by Toyota alone. For example, program management or modularization principles have been introduced by global OEMs over the past decades.

While Toyota was just one aspect of the advancement in new product development methodologies, another scheme was developed by NASA in the 1960s. NASA’s phased project planning or as later called and labored by the U.S. military phased review process. This approach breaks down the product development into discrete stages with a review after each phase. Continuation to the next phase was conditional to the completion of the milestones related to the previous phase. In other words, it is a typical project management approach, but is limited to the development phase only, while marketing or manufacturing functions are not part of this process [94].

On the other hand, the stage gate model has been a dominant approach to NPD in the automotive industry as described by Cooper [49], [93]. Initially, stage gate was part of a sequential methodology to NPD, where all functions provided inputs to the new design in sequence. This was then repeated until the final product met requirements. Just like the phase review process, also Cooper’s stage gate model consists of discrete stages with defined review gates. In addition, a variety of success factors have been implemented to enhance that approach achieving faster time-to-market
or improved project performance in terms of meeting customer requirements. The evolutionary principles around Cooper’s stage gate model: First, the stage-gate system is very much cross-functional. Both, marketing and manufacturing departments have become an integral part of new product development overcoming traditional silos. This so-called extended enterprise model provides a structured methodology necessary for aligning the total organization along lean principles [97]. Also, the decision gates are cross-functional and no-longer owned by one single function. Furthermore, the system is more holistic from idea to product commercialization and has a strong focus on the pre-development phase in order to avoid costly re-work later on. As a result, a much stronger market orientation is required. This so-called front-end loading of the NPD process was crucial to achieve cost savings and reduce overall engineering hours [95]. It later evolved into the modularity principle or platform concept [96], [101].

The next level of evolution was a design-centered model enhancing the confidence in the early stages of NPD via tools such as computer-aided design, failure mode effect analysis, and design for assembly methodologies. The design-centered approach was first employed by General Motors [69]. Concurrent engineering allows the speeding up of the NPD process by enabling certain stages to take place in parallel, thus optimizing cycle time [70], [94], [98]. In other words, it is in contrast to the original form of the stage-gate model, which allowed only moving to the next phase once the requirements of the previous phase have been met. Many studies have shown the benefits of concurrent engineering in terms of improving the cycle time of NPD projects [99], [100]. The introduction of program management, Failure mode and effects analysis (FMEA), communication and decision making along the NPD matrix further improves cost, quality and time parameters (similar to what has been described along the tools for the Lean Product Development System). 

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Today, global car makers have widely adopted and adapted for their needs the relevant models and tools available. By applying these approaches over the past decades, development times for OEMs have been reduced from 6 to 3 years on average considering a complete new vehicle and powertrain program development. In order to further speed-up time to market, a recent trend by OEMs has been to extend the program life cycle by introducing simply a face lift (in other words a new hood) for the existing vehicle platform. While this is a great possibility for OEMs to increase the number of new product launches, it is not sufficient to cope with the new competitive pressures in the automobile industry. A variety of emerging tools enhancing NPD in the car industry in order to cope with increasing competitive pressures will be dealt with in the following as well as the consecutive chapter.

3.3. EMERGING OEM’S NPD APPROACHES

This section highlights the various NPD approaches found by OEMs in emerging markets. The author focuses his analyses on the BRIC countries. No specific approach to innovation is found in Brazil other than a strong public funding that manifests itself in penetration of bio-ethanol and related technical solutions – referred to as policy driven research. Nevertheless, some OEMs entertain local competence and technology centers that have come-up with newly born technologies such as the flex-fuel engine (companies like Bosch, Magna Marelli, Renault, GM, VW). A similar situation is present in Russia. The mainly government-driven R&D system for local players – with many research institutions or universities involved – is not efficient enough to turn knowledge into serious products that are sufficiently innovative to compete with foreign competition. The only way for local players to innovate is by developing partnerships with foreign players (e.g. Renault acquired a 25% stake in AutoVAZ). Local suppliers face the same issues when it comes to modernizing their product range. Some global suppliers are now becoming active in Russia.
India’s OEMs have their own approaches to innovation and three core elements have been identified [21]-[23]:

1. Co-opetion (“fraternity building”) is an approach similar to open-source architectures, where OEMs engage suppliers to provide intellectual capital to support development projects at little or no cost. For example, Hero Honda Motorcycles has managed to persuade dealers to invest capital in component plants and dealerships [27].

2. Indigenous innovation aims to deliver consumer value along the product life cycle. Brand-supporting technology, product or service features do not necessarily have to come from the OEM itself. Simultaneously, OEM life cycle costs are reduced by employing the service skills of independent roadside mechanics with low cost garages, which includes the spare parts business not necessarily sourced via OESs. Another example is Tata which has shifted the assembly of mirrors, wipers and other accessories from its production sites to dealerships that benefit from their advantageous cost structures. In summary, Tata, Mahindra and others have continuously innovated many processes to the benefit of their customers [31].

3. Institution building is geared towards gaining a competitive advantage through having an input into the firm’s outer environment. Tata has achieved this by building some social infrastructure, such as schools and medical facilities, around company locations. This creates a partnership with the society and makes employees and local workforce loyal, committed and less expensive from a total cost of ownership (TCO) perspective. Another example is Mahindra’s variation of Apple’s idea of providing computers to schools free of charge. Mahindra provides driving schools that in turn foster the creation of a new customer base in a country with mostly first-time buyers [20].
These approaches are often disregarded by global players as they are somewhat alien to traditional processes. As noted earlier, the Nano is only one example emerging from Indian’s car industry of how the principles described can be beneficial.

In China, a disruptive innovation pattern [29] [30] i.e. low cost innovation, is evident. Here universities have their own departments for patent exploitation. Chinese enterprises though – whether state-owned or private – often do not have the means or patience to conduct basic and applied research [28]. This situation is also seen in automotive enterprises, where designs are often brought in cost free by foreign JV partners. Disruptive patterns of innovation at well-known Chinese appliance, IT or telecom enterprises manifest themselves in local players who also influence global markets by providing innovative products at low prices. Global players, on the other hand, would traditionally ask for a premium while providing customers with additional features [24] [26]. In the car business a similar approach can be seen. JVs often obtain their original design from foreign partners virtually free, but with the advantage of local market intelligence, and innovate the vehicle to suit local customer groups. The disruptive aspect of this is the fact that Chinese car makers are leapfrogging conventional innovation patterns and exploiting the opportunities of EVs by leveraging local supply chain advantages [33]. By offering innovation at low cost, a disruptive business model increases competition for global OEMs. Moreover, Chinese suppliers are able to adopt foreign manufacturing equipment to fit their local manufacturing footprint. This is characterized by a high degree of manualization, as compared to automated processing from the western world, which allows them to achieve cost benefits and tap into the “China price” [25]. It is expected that more and more innovative car players will emerge to grab opportunities that may arise from small car segments with alternative powertrains, such as electric drives for example, using the strength of low cost innovation. Chery and Geely are good examples of players that built on cloned solutions while leveraging
China’s low-cost base to provide vehicles at low cost – also referred to as the “Clone, Plug and Play” model [20].

In the auto industry segment of small cars with alternative powertrains such as electric drives, there are opportunities to use the power of low-cost innovation in particular by Chinese car makers. It is expected that increasing numbers of innovative auto industry players will emerge to take advantage of these opportunities.

In summary, what has been outlined are the disruptive patterns seen in China and India that are breaking open traditional value propositions by providing customer value at low price instead of a premium one. The result, which is linked to large market volumes and environments with a very high percentage of first-time buyers, enables the growth of domestic players and will eventually lead to their presence in mature markets as well. Nevertheless, global OEMs can avail of the advantages of emerging markets when it comes to R&D by defining their strategy for off-shore research beyond just manufacturing [24]. This requires adaptation of the existing
NPD approaches perfected over many years but now only suited to traditional markets in the triad regions.

For reasons of completeness, the author highlights the situation in both, Brazil and Russia. Looking at the industry sector in Brazil, although most companies rely on knowledge transfer, some incorporate their Brazilian engineering facilities into their global strategy. No specific approach to innovation is found in Brazil other than a strong public funding, which has shown its effect in penetration of bio-ethanol and related technical solutions – referred to as policy driven research. Nevertheless, some concept engineering, where R&D for new products is done, holds the whole development chain in Brazil including local competence and technology centers that have come-up with newly developed technologies such as the flex-fuel engine (companies like Bosch, Magna Marelli, Renault, GM, VW). The following examples support this statement: VW Brazil has developed the so-called project Tupi, later renamed to Fox – a global platform for a small car that is available worldwide nowadays. VW Brazilian engineers developed the Gol, leader in sales for almost consecutive 20 years. This model is also exported to China. GM operates part of its global engineering activities in their center part of its São Caetano plant, where 2,500 engineers are fully dedicated to developing new products, like Opel/Saturn Astra (in Brazil, the same vehicle is called GM Vectra GT).

In Russia, the mainly government driven R&D system for local players with many research institutions or universities involved is not efficient enough to turn knowledge into series products that are innovative enough to compete with foreign competition. The only way for local players to innovate is by getting into partnerships with foreign players (e.g. Renault acquired a 25% stake in AvtoVAZ). Local suppliers face the same issues when it comes to modernizing their product range. Some global suppliers are now getting active in Russia. MAGNA, for example, established a technical center with approximately 15 engineers in the automotive cluster.
near Nizhniy Novgorod to support initiatives with its GAZ alliance - which is currently in question though. In summary, both Brazil and Russia have yet no distinct NPD approaches from local players that would bear any competitive pressure to traditional car makers.

3.4. TRADITIONAL OEM’S NPD APPROACHES

The following section outlines the NPD approaches of traditional or global OEMs in emerging markets (i.e. offshore NPD) and describes the differences between localization and product adaptation.

Manufacturing engineering: A first step when moving manufacturing sites offshore is to set up a dedicated manufacturing engineering department. The objective here is to ensure technical compliance with global OEM standards, as well as to provide support during manufacturing operations.

Local sourcing breaks away from traditional supply routes. Local manufacturing involves using local parts to increase the advantages of low-cost manufacturing along the value chain downstream. The investment required for developing local suppliers can be funded from the savings that result from using local sources for global production activities. Here, the objective is to set up local engineering support offices (ESO) to assist suppliers in complying with global technical requirements. Assistance is provided during the entire process, from supplier selection, to the product part approval process (PPAP), to the start of production. It also includes lifecycle management.

Local product adaptations facilitate proximity to markets. A local engineering hub is usually developed with a sourcing support office. A local hub allows for a better understanding of local market requirements and also facilitates evaluation of local products in their respective target market.
Activities range from simple product adaptations to complete development of vehicles for local markets. Such development might include not only changes in design, but also de-contenting to compete with local players (e.g. an approach that Audi employs for the China market).

Offshoring non-core engineering services take advantage of low labor costs and local talent pools. Non-core engineering services include, for example, CAD design and computer software programming, which are often carried out in offshore centers. For example, the strong focus on IT in India is reflected by the fact that 150 Fortune 500 companies operate R&D off-shoring center in India. Automotive manufacturers Ford and Daimler are two such examples. Offshoring of such activities is beneficial because the labor pool for some of these jobs has become scarce in developed industrial nations. Capacity utilization may be challenging, since demand for such specific development items may vary when only one customer is supplied.

Local R&D hubs may serve as an integral part of an international R&D organization by handling the development of an entire module or system. For example, they may be responsible for the dashboard or for the interior panels (e.g. Daimler in India). A local R&D hub is the most promising type of offshore R&D in terms of cost benefits. However, it is also the most challenging for traditional companies because top management must initiate organizational changes in order to fully exploit all benefits. Some OEMs may choose to establish a local R&D hub through their tier-1 suppliers.

Research collaboration promotes new technologies that shape future markets. Incentives for new energy vehicles have been a major part of public research policy in China. Although emission and safety regulations have lagged behind international benchmarks, however, they are expected to move towards conformity in the near future. This explains why some players have started to use technology demonstration fleets and have initiated research collaboration with universities. They not only want to gain
an understanding of future market developments, but also hope to shape public policy development. Also, some global players have research monitoring offices in Russia to track any uprising trends, while tapping into the research pool.

The following figure provides a summary of the various NPD approaches of traditional OEMs while entering emerging markets.

Fig. 3-2 Overview of NPD approaches of traditional OEMs

In the following chart, the six mentioned approaches are depicted along with a ranking of various multinational OEMs based on their current China operations.
In this ranking, VW and GM are clear winners. They offer typically cars in the volume segment and are hence closer to the Chinese consumer groups. On the other hand, luxury brands such as BMW and Mercedes-Benz (Daimler) are rather poor in terms of their localized R&D activities. The reasons for this are two-fold: the lower volume for luxury car makers does not allow having larger R&D investments outside their home country. Furthermore, later market entries as well as a general fear of intellectual property rights (IPR) violations are further reasons for this result [59]. The following chart shows R&D intensity versus market share in China of selected multinational OEMs.

<table>
<thead>
<tr>
<th>No</th>
<th>R&amp;D set-up by multinational OEMs</th>
<th>VW</th>
<th>GM</th>
<th>Toyota</th>
<th>PSA</th>
<th>BMW</th>
<th>Daimler</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Manufacturing engineering (for plant operations)</td>
<td>🌒</td>
<td>🌒</td>
<td>🌒</td>
<td>🌒</td>
<td>🌒</td>
<td>🌒</td>
</tr>
<tr>
<td>II</td>
<td>Localization and local sourcing (including export sourcing)</td>
<td>🌒</td>
<td>🌒</td>
<td>🌒</td>
<td>🌒</td>
<td>🌒</td>
<td>🌒</td>
</tr>
<tr>
<td>III</td>
<td>Local product adaptation (e.g. local engine adaptation, etc.)</td>
<td>🌒</td>
<td>🌒</td>
<td>🌒</td>
<td>🌒</td>
<td>🌒</td>
<td>🌒</td>
</tr>
<tr>
<td>IV</td>
<td>Non-core competency engineering services off-shoring (e.g. CAD)</td>
<td>🌒</td>
<td>🌒</td>
<td>🌒</td>
<td>🌒</td>
<td>🌒</td>
<td>🌒</td>
</tr>
<tr>
<td>V</td>
<td>R&amp;D hub with off-shore module development</td>
<td>🌒</td>
<td>🌒</td>
<td>🌒</td>
<td>🌒</td>
<td>🌒</td>
<td>🌒</td>
</tr>
<tr>
<td>VI</td>
<td>University research collaborations and public-private partnerships</td>
<td>🌒</td>
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</tbody>
</table>

Fig. 3-3 Overview of R&D set-up by multinational OEMs in China and ranking by selected manufacturers.
Of course, it does not suggest that a lower R&D intensity will result into a lower market share in China. For example, the European Union Chamber of Commerce in China has conducted the European Business Confidence Survey in 2011 and concluded that a later market entry has a significant influence on market penetration, profitability, etc. for foreign companies operating in China. Nevertheless, volume OEMs have no choice but to localize R&D in China as they are in some cases competing with Chinese low cost manufacturers. The distinct R&D approaches of Chinese OEMs have been covered in the previous section.

European carmakers, and in particular German carmakers, have already had global success and in some cases dominate the innovations in the premium segment. This can be linked to their integrated NPD approach [32], which comprises system development, modularity concepts, in-house R&D value chain, and rigorous planning processes. To compare the automotive R&D approaches in China and Europe, based on a generic model for new product development the pre-development and pure research phase always appears to be outsourced in China. Also, tools such as
modularity principles are less evolved. On the other hand, ‘manualization’ of manufacturing processes and large scale low-cost innovation compensate for this. In both cases, distinct approaches are creating value by leveraging networks of innovation [31] that combine global aspects applied to a local environment.

The innovation approaches studied in this section are critical elements of the toolbox for the emerging NPD methodology. Cooper [49] describes a generic model known as ‘stage gate’ that distinguishes between technical and market-related activities. Yet, the innovation approaches here show the specific tools that are needed to cope with new competitive pressures in the automotive industry. Another element that becomes apparent is that stakeholder integration beyond the company that develops the new product is needed. NPD toolbox, automotive specific detailing of NPD methodology and wider stakeholder integration are core elements of the research findings presented in this research.

3.5. CONCLUSION

In summary, this chapter examines existing NPD approaches of both emerging and traditional car makers. The author has researched extensively the distinct differences and highlights from the past 20 years. NPD approaches around previously have only been covered briefly in the introduction section of this chapter.

No specific approach to innovation is found in Brazil except for a strong public funding focused on penetration of bio-ethanol and related technical solutions – referred to as policy driven research. In Russia, the mainly government-driven R&D system for local players – with many research institutions or universities involved – is not efficient enough to turn knowledge into serious products that are sufficiently innovative to compete with foreign competition.
India’s OEMs have their own approaches to innovation and three core elements have been identified [21]-[23]: 1. Co-opetition (“fraternity building”), 2. Indigenous innovation and 3. Institution building. These approaches are often disregarded by global players as they are somewhat alien to traditional processes.

In China, a disruptive innovation pattern [29] [30] i.e. low cost innovation, is evident. Here, universities have their own departments for patent exploitation. Chinese enterprises though – whether state-owned or private – often do not have the means or patience to conduct basic and applied research [28]. Moreover, Chinese suppliers are able to adopt foreign manufacturing equipment to fit their local manufacturing footprint. This is characterized by a high degree of manualization, as compared to automated processing from the western world, which allows them to achieve cost benefits and tap into the “China price” [25].

On the other hand, traditional car makers deploy a whole range of tools depending on maturity of market entry while penetrating the BRIC countries. Six distinct approaches have been identified by the author: Localization & Local Sourcing, Manufacturing Engineering, Local Product Adaptation & Vehicle Engineering, R&D Hub with Off-shore Module Development, Non-core Engineering Off-shoring, and Research Collaboration.

While many models for NPD exist in order to cope with new competitive pressures in the automotive industry, no ‘Holy Grail’ approach exists that allows benefiting from various NPD models. The emerging NPD methodology is designed and validated by the author that will show a way out of existing challenges that allows providing an integrative approach forward. The emerging NPD methodology is shown in chapter 5.
CHAPTER 4 VALIDATION OF RESEARCH RESULTS

4.1. INTRODUCTION

This chapter highlights the key steps in validating the emerging NPD approach for total system innovation. Hereby the following elements are considered: Firstly, the comparisons of the emerging NPD approach with conventional approaches in the car industry. The examples (as shown in Chapter 6 – Emerging Automotive NPD Methodology Applied) demonstrate that the emerging methodology allows for well-to-wheel expansion and employs low cost innovation and system innovation to cope with new competitive pressures. Validation of the NPD methodology is also achieved through expert interviews. With the development of IDEF0 models, for the various building blocks, results can be compared on a step by step basis at each phase of the NPD process individually. Key elements are time-to-market and R&D cost for new vehicle programs, which are critical in today’s ever competitive environment. Overall, the emerging NPD methodology yields efficiency improvements while applying the set of distinct tools needed to compete in a changing world (here referring to the tool box illustrated in Table 5-2 Overview of selection of NPD tools).

While the first dimension was primarily focused on comparing conventional process outputs with the emerging NPD approach outputs in terms of time and cost, the second dimension was to look at a more holistic picture: to meet the requirements of the future transport system such as smart cities for example. Here, an empirical analysis shows how conventional NPD approaches are limited in their capability to meet future
transport requirements, and originally gives motivation to create an emerging NPD methodology that is able to cope new competitive pressures such as holistic energy integration for example. This is considered a key element in demonstrating how the emerging NPD methodology is able to comply with the paradigm changes in the industry due to various factors. These factors comprise technology evolution, regulatory development and consumer behavior and have been assessed in frameworks to stress how the emerging approach is meeting future requirements in automotive NPD, whereas conventional NPD has its limitations.

4.2. OVERVIEW

In proposing and validating the emerging NPD methodology the author uses a series of iterative expert interviews to support empirical research findings. The iteration refers to 3 steps: firstly, understanding emerging NPD tools; secondly, discussing and refining the NPD methodology; and thirdly, testing the emerging NPD methodology with a specific case. After having performed initial secondary and primary research, the author has built an understanding of new competitive pressures in the automotive industry (see Chapter 2 – New Competitive Pressures in the Automobile Industry). A set of tools has been investigated and further developed to cope with these pressures. At the same time, the author provides various insights into NPD characteristics specific to the automotive industry beyond the traditional stage gate methodology (see Chapter 3 – Research of Innovation Approaches in the Automobile Industry). Consequently, an emerging NPD methodology for the automotive industry supported by a set of tools has been designed. Primary research and illustrative case examples explain and discuss how the methodology and toolbox has been further refined and validated (presented in Chapter 5 – Emerging Automotive NPD Methodology). Figure 4-1 illustrates the holistic view of the research approach and validation as shown later in this chapter.
4.3. RESEARCH METHODOLOGY

In order to validate the emerging NPD approach for total system innovation, the following dimensions are considered:

Firstly, a comparison of the newly developed NPD approach using well-to-wheel expansion, employing low cost innovation and system innovation, with conventional NPD approaches in the car industry. This assumes that the same technology is being developed and results are compared based on modeling the emerging approach and benchmarking with conventional ones. Validation of the NPD flow is achieved via expert interviews. By creating models for the various building blocks, it is shown to also assess the results from a quasi-quantitative perspective. Here, time-to-market and R&D cost for new vehicle programs are being compared. Overall, the author demonstrates how the emerging NPD methodology will yield efficiency improvements in terms of time and cost vs. conventional frameworks.

The second dimension to validate the emerging methodology is of crucial importance. While the first dimension was primarily focused on comparing conventional process outputs with the emerging approach outputs in terms of time and cost, the second dimension assesses more a holistic picture: how to meet the requirements of the future transport model in smart cities. Here, an empirical analysis helps to assess how conventional NPD approaches are limited in their capability to meet future transport requirements, and give motivation to create an emerging approach that is able to cope with holistic energy integration (part of a the new competitive pressures in the automotive industry). This is considered as the key element in demonstrating how the emerging NPD methodology is able to comply with the paradigm changes in the industry due to various factors. These factors comprise technology evolution, regulatory development, consumer behavior and so forth (see Chapter 2 – New Competitive Pressures in the Automobile Industry) and are assessed in frameworks to stress how the...
emerging approach is meeting future requirements in automotive NPD, while conventional NPD has its limitations. The following figure illustrates the overall methodology from secondary and primary research to validation of the overall findings.

Fig. 4-1 Holistic view of research approach

In addition to that, the author made use of so-called action research. Action research is either research initiated to solve an immediate problem or a reflective process of progressive problem solving led by an individual working with others in teams or as part of a \"community of practice\" to improve the way they address issues and solve problems. There are two types of action research: participatory action research and practical action research. An action research strategy's purpose is to solve a particular problem and to produce guidelines for best practice \[107\]. Action research involves actively participating in a change situation, often via an existing organization, whilst simultaneously conducting research. This was the perfect fit for the author's background who was working in China as an automotive engineer. The aim was to improving strategies, practices and knowledge of the environments which the author faced throughout his time in China. Kurt Lewin, then a professor at MIT, first coined the term \"action research\" in 1944. In his 1946 paper \"Action Research and Minority Problems\" he described action research as \"a comparative research on the conditions and effects of various forms of social action and research leading to social action\" that uses \"a spiral of steps, each of which is composed of a circle of planning, action and fact-finding about the result of the action\"
CHAPTER 4 VALIDATION OF RESEARCH RESULTS

[108]. Action research is an interactive inquiry process that balances problem solving actions implemented in a collaborative context with data-driven collaborative analysis or research to understand underlying causes enabling future predictions about personal and organizational change [109]. Action research challenges traditional social science by moving beyond reflective knowledge created by outside experts sampling variables, to an active moment-to-moment theorizing, data collecting and inquiry occurring in the midst of emergent structure. “Knowledge is always gained through action and for action. From this starting point, to question the validity of social knowledge is to question, not how to develop a reflective science about action, but how to develop genuinely well-informed action — how to conduct an action science” [110]. In this sense, performing action research is the same as performing an experiment, thus it is an empirical process and was a core element in validating the research findings as presented here thanks to the author’s industry experience and active involvement in the challenges described in Chapter 1.

4.4. PRIMARY RESEARCH

Primary research consisted of a multiple expert interviews to support empirical research. The author has been involved in a focus group study of emerging automotive consumers in China in order to better understand emerging consumer groups and their distinct behaviors [103]. For the expert interviews, 48 interviews were conducted from mid-2010 to early 2013. The selection of the interview partners was based on the following three step approach: (i) defining the type of companies that need to be interviewed; (ii) creating a long list of potential target companies; and (iii) shortlisting based on relevance for the research as well as personal contacts the author had with representatives from the target companies. The interview process was a core step to be able to refine and validate the emerging NPD methodology. Interview partners were from three different hierarchical categories: professionals (e.g. engineers); middle management; and top management.
Interviews with professionals lasted up to two hours while interviews with top/middle management were of half an hour to one hour duration. The categories of companies interviewed were: emerging market OEMs; global OEMs; industry associations; infrastructure providers; management consultancies; policy makers; and suppliers. Due to the nature of this research – aimed to refine and validate an emerging NPD methodology allowing to cope with new competitive pressures in the automotive industry – the type of interviews conducted were purely qualitative. The questions evolved from the initial research phase to the final validation phase of the research findings. During the first set of interviews the author focused primarily on gaining an understanding of new competitive pressures in the automotive industry. This has provided the basis for developing a set of tools to cope with these pressures as well as to better articulate the research gap. All this has been achieved by asking questions about the core phases of the existing NPD process, interfaces with other stakeholders, employment of tools to cope with new challenges and so forth. During the validation phase, the interviews consisted of the author presenting the IDEF0-based emerging NPD methodology and associated tools for discussion and for refinement in some areas. This also allowed for the discussion of case examples from the perspective of the interview partners (e.g. if you were to develop a new vehicle program with this methodology and in the context of your company, how would you go about it?). The interview guide utilized is shown in the appendix (see Appendix A.4 Expert Interview Guide). It was developed based on the authors experience from developing VOC interviews tailored to validating core elements of this research. It was linked to the iterative approach commencing with an understanding of emerging NPD tools, then discussing and refining the emerging NPD methodology and lastly, testing the applicability of the NPD methodology using test cases. An overview of the interviews conducted is shown in the following table.
<table>
<thead>
<tr>
<th>Category</th>
<th>Company Name</th>
<th>No. of interviews</th>
<th>Function(s)</th>
<th>Hierarchy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emerging market OEM</td>
<td>FAW</td>
<td>1</td>
<td>Research</td>
<td>P</td>
</tr>
<tr>
<td>Emerging market OEM</td>
<td>BAIC</td>
<td>4</td>
<td>Engineering, Strategy, Manufacturing, Procurement</td>
<td>P, M, T</td>
</tr>
<tr>
<td>Emerging market OEM</td>
<td>SAIC</td>
<td>1</td>
<td>Engineering</td>
<td>M</td>
</tr>
<tr>
<td>Emerging market OEM</td>
<td>BYD</td>
<td>2</td>
<td>Engineering</td>
<td>P</td>
</tr>
<tr>
<td>Emerging market OEM</td>
<td>Wanxiang</td>
<td>2</td>
<td>Engineering, Product Management</td>
<td>M</td>
</tr>
<tr>
<td>Emerging market OEM</td>
<td>PATAC</td>
<td>1</td>
<td>Engineering</td>
<td>M</td>
</tr>
<tr>
<td>Emerging market OEM</td>
<td>Mahindra</td>
<td>1</td>
<td>Engineering</td>
<td>M</td>
</tr>
<tr>
<td>Emerging market OEM</td>
<td>Tata Motors</td>
<td>1</td>
<td>Engineering</td>
<td>M</td>
</tr>
<tr>
<td>Global OEM</td>
<td>VW</td>
<td>3</td>
<td>Engineering, Strategy, Product Management</td>
<td>P, M</td>
</tr>
<tr>
<td>Global OEM</td>
<td>BMW</td>
<td>3</td>
<td>Engineering, Sales, Product Management</td>
<td>P, M</td>
</tr>
<tr>
<td>Global OEM</td>
<td>Mercedes-Benz</td>
<td>7</td>
<td>Engineering, Procurement, Research, Strategy, Manufacturing, Product Management, Sales</td>
<td>P, M, T</td>
</tr>
<tr>
<td>Industry Association</td>
<td>ACEA</td>
<td>3</td>
<td>Government Affairs</td>
<td>M, T</td>
</tr>
<tr>
<td>Infrastructure Provider</td>
<td>GE</td>
<td>3</td>
<td>Sales, Product Management, Marketing</td>
<td>P, M</td>
</tr>
<tr>
<td>Infrastructure Provider</td>
<td>Car2go</td>
<td>1</td>
<td>Business Development</td>
<td>M</td>
</tr>
<tr>
<td>Infrastructure Provider</td>
<td>RWE</td>
<td>2</td>
<td>Business Development, Strategy</td>
<td>M</td>
</tr>
<tr>
<td>Infrastructure Provider</td>
<td>EnBW</td>
<td>1</td>
<td>Product Management</td>
<td>M</td>
</tr>
<tr>
<td>Infrastructure Provider</td>
<td>Total</td>
<td>1</td>
<td>Product Management</td>
<td>P</td>
</tr>
<tr>
<td>Infrastructure Provider</td>
<td>Indian Oil</td>
<td>1</td>
<td>Product Management</td>
<td>M</td>
</tr>
<tr>
<td>Infrastructure Provider</td>
<td>CNPC</td>
<td>1</td>
<td>Product Management</td>
<td>P</td>
</tr>
<tr>
<td>Management Consulting</td>
<td>Roland Berger</td>
<td>3</td>
<td>Strategy</td>
<td>P, M, T</td>
</tr>
<tr>
<td>Management Consulting</td>
<td>McKinsey</td>
<td>1</td>
<td>Strategy</td>
<td>M</td>
</tr>
<tr>
<td>Policy Maker</td>
<td>NDRC</td>
<td>2</td>
<td>Government Affairs</td>
<td>M</td>
</tr>
<tr>
<td>Supplier</td>
<td>Bosch</td>
<td>2</td>
<td>Engineering, Government Affairs</td>
<td>M</td>
</tr>
<tr>
<td>Supplier</td>
<td>Continental</td>
<td>1</td>
<td>Engineering, Research</td>
<td>M</td>
</tr>
</tbody>
</table>

P - Professionals; M - Middle Management; T - Top Management
In the previous and following chapters, the author refers to these expert interviews to underline the validation of the emerging NPD methodology. In the following paragraphs, some of the interview findings are highlighted.

In total, 5 Chinese OEMs have been interviewed (FAW, BAIC, SAIC, BYD, Wanxiang). FAW, BAIC and SAIC are all state-owned enterprises. As mentioned earlier, many Chinese OEMs have previously relied on public funded research that provided new vehicle concepts almost for free as part of the government planning policies. This has led to an NPD process often commencing in the design phase rather than focusing on vehicle concepts. Another aspect is that these OEMs have formed Sino-foreign joint-ventures that have often come with existing concepts for manufacturing localization. Later, these served as a basis for the SOE OEMs to design their own vehicles, but again omitting critical steps in the concept phase. The author recognizes many of the NPD tools as described in Chapter 3.3. A particularly relevant NPD tool for all Chinese OEMs is low cost innovation. The interviews with private OEMs from China, BYD and Wanxiang, have brought to attention rather unconventional ways to
NPD. Both have their origins not as car maker, but as supplier. BYD was originally the largest battery pack manufacturer for the telecommunications market and Wanxiang commenced as powertrain component supplier. Both have - through disruptive technologies - paved their way into becoming a car maker. Again, this had tremendous impact on their NPD methodology by practically omitting the concept phase and relying on existing vehicle platforms. For example, Wanxiang’s first electric vehicle was nothing else but taking an existing car, removing its conventional powertrain and equipping it with a disruptive pure electric drive. Overall, the author found that tremendous planning cycle exist on paper, but in practice require significant improvisation by the product development teams in order to realize NPD projects on time. Historic hierarchical structures as well as some pure sequential flows of the process require teamwork and working level communication between functions in order to compensate for the lack of overall NPD coordination. In one case the author noted lack of cross-functionality somewhat similar to the late 1960s approach by NASA.

PATAc is an example, where SGM (Shanghai General Motors) and SAIC have formed a joint-venture to offshore low cost car NPD in order to reduce overall engineering cost, improve time-to-market and integrate local market know-how into product development. Here, the NPD process has been widely adopted from GM being characterized by the latest NPD tools such as program management (or in other words Chief Engineer concept), DFx tools, VA/VE tools and modularity principles. Again, the concept phase has been simplified with the focus being clearly on the design and validation phases. Overall, the author concludes that three principle phases are sufficient for NPD and that the concept phase is often disrupted by Chinese OEMs.

The interviews conducted with Indian OEMs included Tata and Mahindra. Tata Motors has a full suite of R&D facilities comparable to that of many OEMs in Europe, and is conducting research and engineering in a similar way that European companies do. Their facilities in India are supported by R&D centers in Korea and UK. The center in Korea focuses
on commercial vehicles, while their European R&D hub in Coventry, UK supports R&D for both passenger cars and commercial vehicles and is fully integrated into the R&D center in Pune, India. The UK center helps them to transfer high-end technologies to India and continue product development there at a significantly lower cost, having made product innovations like the Nano possible. Also, Indian players conduct R&D through cooperative public-private partnerships such as via the Core Group on Automotive R&D (CAR) and the Automotive Research Association of India (ARAI), which is somewhat similar to its European counterparts. These groups bring together domestic and global players for the purpose of conducting joint research on future technology. In summary, the NPD tools as described in Chapter 3.3 were captured during these interviews including cooperation, indigenous innovation and institution building combing process, value chain and partner innovation.

Looking at global OEMs, in particular German players and their affinity to developing premium products, their NPD processes are rather sophisticated. They consist of a combination of stage-gate and concurrent aspects integrating multiple functions through program management and modularity principles. Apart from the NPD tools that have evolved from the car industry, many of the interviewees are not aware of academic descriptions of NPD such as stage gate for example. The author also noted that there is a general division between vehicle platform development and powertrain system development that can be used in multiple vehicle platforms or derivatives. Overall, these care makers are challenged by need to further reduce the development time to below 3 years for new vehicle programs. Since lean principles have migrated through the entire value chain, some progress has been made. Yet, lately such OEMs have unlocked new markets and are required to localize to be able to compete. Traditional NPD methods are not suited for that. Often activities have commenced with localization activities supported by engineering support offices that remain embedded into the existing NPD organization despite being remotely located. The next evolution was to actually modify the vehicle to suit
emerging market needs instead of dumping existing value propositions to customer groups with different needs and behaviors. Typically, these OEMs have brought their existing vehicle concepts and simply used the design phase to adapt the product to local market needs and reflect constraints of localization. This leads to the takeaway that global OEMs adapt the design phase for emerging market NPD. In other words, they do not re-develop from scratch, but leverage large portion of existing systems and components in line with localization requirements. At the same time, focusing on the design phase allows to adapt the product to local tastes from a design perspective, while earlier approaches focused on product management only. Furthermore, when the interviewed OEM group has to cope with zero emission requirements, a whole new set of challenges arises. On the one hand, it is a paradigm change in the industry after having focused all efforts on optimizing the ICE, while now disruptive technologies come into play. Today, an OEM needs to manage a whole set of powertrain technologies in its development process ranging from HEV, PHEV, FCV, EV to various fuel types requiring different powertrain adaptations. In short, these new technologies challenge the OEMs that used to break-up powertrain system development from vehicle platform development. Now, they need to work together and integrate more disciplines earlier in the process. In addition, OEMs need to further collaborate with both, suppliers and infrastructure providers to realize zero emission pathways. None of the OEMs had a suitable fine-tuned process to manage this level of complexity in their NPD phases. The interviewees agreed with the proposed emerging NPD methodology dividing the NPD process into three distinct phases while providing feedback loops. The combination of adapted stage-gate and concurrent elements along with a tool box allowing for emerging market NPD or stakeholder integration for zero emission NPD were considered as critical elements to cope with new competitive pressures in the industry.

Infrastructure providers on the other hand, have no distinct or in some cases no NPD process at all with regards to providing infrastructure for individual mobility. On the contrary, some of the providers (both
utilities and energy companies) are in process of entering such activities as a means to capture more value downstream. For example, RWE considered selling ancillary services while EV car owners are re-charging their vehicle (charging time being considerably longer than fueling conventional vehicles); or CNPC was looking to find more off-take for CNG by providing a network of CNG fueling stations for transportation needs. While the author could not find any NPD specifics, the interviews with these companies were critical to understand the interfaces and stakeholder integration needed to make NPD in a world with increasing emission requirements a success. Furthermore, suppliers play a vital role in the realization of new energy vehicles. In fact, there are only a handful of global system suppliers in the E/E segment that are critical in providing systems and components for the electrification trend in automotive. While this will take away some of the value stream by the OEM, it will also require the OEM to integrate earlier with the supply base. Suppliers themselves often depend on the OEMs discretion to involve them early in the process. No open NPD approach exists due to commercial constraints. There are only a few examples of technology development by a supplier for an OEM with temporary exclusive use in order to provide a competitive edge. Again, no NPD specifics for the vehicle development process itself were gained, but tremendous insight on stakeholder involvement, supplier integration into NPD and current paradigm changes in the industry were obtained. The following table summarizes the key highlights from the interviews per category.

Table 4-2 Summary of lessons learnt from interview findings

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinese OEMs</td>
<td>have traditionally relied on public research funding</td>
</tr>
<tr>
<td>Low cost innovation</td>
<td>and “Clone, plug and play” are key NPD tools utilized by Chinese OEMs</td>
</tr>
<tr>
<td>Co-opetition, indigenous innovation and institution building</td>
<td>are key NPD tools utilized by Indian OEMs</td>
</tr>
<tr>
<td>Global OEM’s NPD methodology</td>
<td>consists of a combination of stage-gate and concurrent aspects integrating multiple functions through program</td>
</tr>
</tbody>
</table>
management and modularity principles

Global OEMs are challenged with their existing NPD model to cope with emerging market requirements and zero emission vehicles.

Global OEMs interview partners agree with the proposed emerging NPD methodology and tool box as a way out to cope with the mentioned challenges.

Infrastructure providers are only at the beginning of their understanding of NPD and the need for integrating into the OEMs NPD process in order to have any meaningful commercial product.

Suppliers in the E/E space take more and more of the total vehicle value chain by providing key systems for the electrified vehicle.

4.5. CASE STUDY BASED RESEARCH

The author dedicates a whole chapter to providing examples on how the emerging automotive NPD methodology can be put into action with focus on Chinese and German automobile industries and using action research to leverage his own experience. Chapter 6 illustrates various examples of that. The emerging methodology is informed and validated through a case study based approach that shows, for example, how emerging market players disrupt the concept phase, while global OEMs adapt the design phase while trying to comply with emerging automotive trends. As mentioned in the introduction, a cornerstone of the new NPD method is the demand for zero emission. This is demonstrated via new business models, while overall competitiveness is achieved through stakeholder integration facilitated by social networks. Parts of these examples are an illustration on how to make use of the NPD toolbox that allows coping with new competitive pressures. The findings of the research are confirmed by empirical research through a series of expert interviews by taking a range of experts over the various examples to illustrate the implementation of the methodology. See Table 4-1 Overview of primary research interviews. In summary, the various illustration examples are being
used to demonstrate an implementation of the methodology in practice. This helped to further refine and validate the emerging NPD methodology. The following figure shows a sketch on this has been realized.

Fig. 4-3 Verification of NPD methodology
The following chapter will show a variety of emerging automotive NPD examples that have been confirmed through expert interviews by the above illustrated approach. Depending on the example chosen, a certain description of inputs and boundary situation is provided so that it can impact the selection of tools from the NPD tool box that feed into the NPD methodology. Then, the specific situation and tools are applied to the methodology and different situations are being illustrated. Furthermore, these examples have been validated through expert interviews in order to verify the applicability of the methodology in practice. As mentioned in section 4.3, this was an iterative approach and initially helped to refine the methodology depending on the feedback from the expert interviews.

4.6. CONCLUSION

In short, the author has developed an emerging NPD methodology that is able to cope with new competitive pressure in the automotive industry. The methodology is informed by various literature studies and makes use of a NPD toolbox that shows the latest tools needed to cope with new competitive pressures. The methodology has then been validated through expert interviews and action research by the author himself. By means of providing case study examples, the author further refined the methodology in order to verify its applicability in practice.
CHAPTER 5  EMERGING AUTOMOTIVE NPD METHODOLOGY

5.1. INTRODUCTION

This section makes use of the previously introduced concepts based on both literature and empirical research. The author describes the validated emerging NPD methodology for the automotive industry as part of his research findings in order to provide carmakers with a way forward in coping with new competitive pressures in the sector. The emerging NPD methodology essentially consists of three core phases: 1. Vehicle conceptualization, 2. Design related to the vehicle, and 3. validation of design. It is embedded in the wide enterprise system relevant to the stakeholders from strategy, marketing, sales and manufacturing departments and OEM partners in the entire operation cycle. The author provides a tool box that helps in each phase in order to cope with the new competitive pressures in the automobile industry.

5.2. OVERVIEW

The emerging NPD methodology enables designers to address holistically all the challenges described earlier and allows them to generate highly energy efficient transportation pathways or vehicle products suited to emerging markets in increasingly competitive environments and so forth. These challenges cannot be met with traditional NPD approaches as seen in the previous chapters. The emerging NPD methodology and associated
toolbox achieved the following aspects: (i) expansion from tank-to-wheel to well-to-wheel as part of the R&D framework of automotive OEMs; and (ii) utilization of low-cost innovation approaches as part of vehicle system integration. The author uses the IDEF0 modeling tool-set to describe and illustrate the emerging NPD methodology (see the following section for a description of IDEF0). The following table shows relevant references that have been used as a basis to propose a new NPD methodology. It links the various IDEF0 Nodes and highlights characteristics per reference.

Table 5-1 Overview of references and its links to IDEF0 Nodes

<table>
<thead>
<tr>
<th>Link to IDEF0 Node</th>
<th>Characteristics</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-1: Contextual overview – Develop new vehicle product in the context of the wider enterprise and key stakeholders</td>
<td>Seven stage NPD model</td>
<td>[49]</td>
</tr>
<tr>
<td></td>
<td>Co-creation along the supply chain</td>
<td>[31]</td>
</tr>
<tr>
<td></td>
<td>Technology &amp; innovation management</td>
<td>[26]</td>
</tr>
<tr>
<td></td>
<td>Collaborative innovation with suppliers</td>
<td>[35], [36]</td>
</tr>
<tr>
<td></td>
<td>Systems approach &amp; environmental impact</td>
<td>[34]</td>
</tr>
<tr>
<td>A0: First level detail – Develop new vehicle product V-shaped systems engineering approach</td>
<td>NPD framework</td>
<td>[37], [39]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[38]</td>
</tr>
<tr>
<td>A1: Conceptualize Vehicle</td>
<td>Tailoring products to new consumer needs</td>
<td>[4]</td>
</tr>
<tr>
<td></td>
<td>Complying with local policy requirements</td>
<td>[18]</td>
</tr>
<tr>
<td></td>
<td>Novel powertrain technologies</td>
<td>[14]</td>
</tr>
<tr>
<td></td>
<td>Zero emission NPD</td>
<td>[40], [41]</td>
</tr>
<tr>
<td>A2: Design Vehicle</td>
<td>Disruptive innovation</td>
<td>[29], [33]</td>
</tr>
<tr>
<td></td>
<td>Low-cost innovation</td>
<td>[24]</td>
</tr>
<tr>
<td></td>
<td>Co-operation NPD</td>
<td>[20]</td>
</tr>
<tr>
<td></td>
<td>Modular design</td>
<td>[42], [43]</td>
</tr>
<tr>
<td>A3: Validate Design</td>
<td>Distinctive European automotive NPD</td>
<td>[32]</td>
</tr>
<tr>
<td></td>
<td>Quality management in automotive R&amp;D</td>
<td>[44]</td>
</tr>
</tbody>
</table>

Many approaches have existed prior to this research, such as Cooper’s stage gate model or Concurrent Engineering with its multiple tools ranging from front-end loading to modularity principles. The emerging NPD methodology as developed during this research combines some of the existing tool sets, makes adaptations that are specific to the automobile industry, leverages IDEF0 modeling to describe the methodology and provides a tool box that allows OEMs to cope with new competitive pressures in the industry. The challenges currently faced by the industry cannot be met with traditional NPD approaches. The author illustrates how the emerging NPD methodology copes with all new interfaces early on in the process, rather than re-engineering when the vehicles are already on the
road. To facilitate representation of the NPD methodology, the standard functional modeling language named IDEF0 is utilized. It allows combining both aspects in one chart, a stage-gate but also concurrent engineering elements, while being able to feed-in tools, capabilities and frameworks.

Case examples are used to illustrate and explain how emerging market players disrupt the concept phase, while global OEMs adapt the design phase while trying to comply with emerging automotive trends. Furthermore, zero emission NPD is demonstrated via new business models, while overall competitiveness is achieved through stakeholder integration facilitated by social network enhanced NPD (as one example of the NPD toolbox). In summary, all aspects of emerging trends are addressed providing proof points and insights for the emerging NPD methodology.

5.3. IDEF0 - INTEGRATION DEFINITION FOR FUNCTION MODELING

IDEF0 is a modeling tool used to produce a model or structured representation of the functions of a system and of the information and objects which tie those functions together. A system can be any combination of hardware, software, and people. An IDEF0 model consists of diagrams and text pages describing the diagrams. Diagrams are the major components of a model and this document will concentrate on how to read them. IDEF0 methodology recognizes that successful systems development requires input and validation from the people who will ultimately use the system. Functions are represented by boxes and interfaces are represented by arrows. The boxes represent functions such as activities, actions, processes or operations. Boxes are denoted by an active verb phrase inside the box. Arrows indicate data. In IDEF, data can be information or physical objects. They are named by noun phrases. The position of the arrow indicates the type of information being conveyed. The arrows entering and leaving the boxes on the left and right represent "Inputs" and "Outputs",
respectively. Inputs represent data needed to perform the function. Outputs show the data that is produced as a result of the function. The function transforms the inputs into the outputs. Arrows which enter from the top indicate "Controls", or things which constrain or govern the function. Arrows entering the bottom of the boxes are "Mechanisms". Mechanisms can be thought of as the person or device which performs the function. An IDEF model is made up of several diagrams. Each diagram describes in more detail a box from a more general diagram. The process of describing a box in more detail is known as decomposing a function. The more general diagram is called the parent of the detailed diagram. IDEF models are read in a "Top-Down" fashion. The top level diagram, also called the Context or A-0 Diagram, summarizes the overall function of the system which is represented by a single box. The A0 diagram represents the first decomposition of the system. The A0 and all subsequent diagrams must contain 3 to 6 numbered boxes. The numbers help tie the diagrams together. All diagrams are named beginning with the letter A, representing Activity. Each arrow entering or leaving an upper box must also be shown entering and leaving the lower diagram. The location of the boxes on a diagram does not necessarily imply sequence or time. Feedback, iteration, continuous processes, and overlapping can be shown by arrows. An output of one box could feedback to a previous box to reactivate that activity [102]. This is one of the reasons why it has been chosen to illustrate the emerging NPD methodology – it allows both, combining stage-gate and concurrent engineering elements, while providing tools, capabilities and frameworks to enable the methodology.

5.4. DEVELOPING NEW VEHICLE PRODUCTS

The author introduces the emerging NPD methodology by highlighting the interfaces to key stakeholders such as consumers and other enterprise functions (e.g. strategy, marketing, sales and manufacturing departments & partners) in order to provide context within the extended
enterprise and stakeholder environment. The following figure depicts a contextual overview of the methodology around “develop new vehicle product”.

Fig. 5-1 Contextual overview – IDEF0 A-1 Develop new vehicle product in the context of the wider enterprise and key stakeholders
New knowledge from new or maturing technologies, competitor moves, changing stakeholder needs and lessons learnt from production are the inputs to the methodology. The activity of developing new vehicle products is triggered by the overall NPD portfolio strategy (C1 is the result of “manage & develop NPD portfolio strategy” and provides the decision for “develop new vehicle product”), assuming that one carmaker serves multiple vehicle segments with different product lines. Different tools and capabilities such as engineering talent and the appropriate R&D footprint are needed to deliver the following outputs: (i) overall vehicle feasibility study; (ii) validated design and specification; and (iii) sales volume plan strategy. Tools are critical to cope with new competitive pressures in the automotive industry. The following figure details the “develop new vehicle product” element; it represents the core of the emerging NPD methodology.
Fig. 5.2 First level detail – IDEF0 A0 Develop new vehicle product

Node: A0  Title: Develop new vehicle product  No. 2
It consists of three essential elements: (i) concept phase where the vehicle is conceptualized; (ii) design vehicle phase that translates the high-level concept into a vehicle product specification; and (iii) validation phase where the prototype is validated by using sample parts from suppliers. In the concept phase, marketing, strategy and research teams evaluate various new vehicle concepts until a final high-level product specification is agreed. The author will show later on that this phase is underrepresented within Chinese car makers as many vehicle concepts are simply copied. During the development phase, the program management team executes the actual product development based on the requirement specification together with various suppliers, purchasing departments, finance, sales and marketing and production planning. Various rounds of testing allow for validation, if product requirements are met during the validation phase for both components and complete vehicle designs. Essentially, this also includes the vehicle type approval ensuring that the vehicle complies with market specific technical regulations.

For each of the phases, the author provides a set of tools to help designers cope with new competitive pressures in the automobile industry. The following table shows a selection of tools that are highlighted in this research. They feed into M1; examples are shown in Chapter 6.

### Table 5-2 Overview of selection of NPD tools

<table>
<thead>
<tr>
<th>Automotive NPD tool box (excerpt)</th>
<th>Relevance for emerging NPD phases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co-operation</td>
<td>Develop new vehicle product</td>
</tr>
<tr>
<td>Indigenous innovation</td>
<td>Conceptualize vehicle</td>
</tr>
<tr>
<td>Institution building</td>
<td>Develop new vehicle product</td>
</tr>
<tr>
<td>Low cost innovation</td>
<td>Conceptualize vehicle</td>
</tr>
<tr>
<td>&quot;Clone, Plug and Play&quot;</td>
<td>Design vehicle</td>
</tr>
<tr>
<td>Local product adaptation</td>
<td>Design vehicle</td>
</tr>
<tr>
<td>Research collaboration</td>
<td>Conceptualize vehicle</td>
</tr>
<tr>
<td>Modularization</td>
<td>Design vehicle</td>
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<tr>
<td>Well-to-Wheel optimization</td>
<td>Conceptualize vehicle</td>
</tr>
<tr>
<td>Total system integration</td>
<td>Develop new vehicle product</td>
</tr>
<tr>
<td>Social networking</td>
<td>Develop new vehicle product</td>
</tr>
</tbody>
</table>
As a recap of what has been shown in the chapter 3, the following provides a brief illustration of these tools. Co-opetition also referred to “fraternity building” is basically the principle of using economies of scale (e.g. one supplier developing the same component for multiple OEMs without modification, or using an existing design from a component that has been localized by a global player). This tool is used by both Indian and Chinese OEMs. Indigenous innovation is best illustrated by Indian OEMs that innovate along the value chain (e.g. using third parties to do maintenance on their behalf instead of building a network themselves or involving the dealerships in the last step of vehicle assembly to save cost). Institution building is another tool employed by Indian OEMs that for example provide free driver training in order to grow the addressable customer base. Low cost innovation is seen with Chinese OEMs that are able to provide premium features without charging a premium price. This is very much linked to their distinct capability of taping into the “China price”. “Clone, plug and play” is another tools utilized by Chinese OEMs that make use of existing designs instead of developing vehicles from scratch. For example, one OEM would use an existing vehicle, take-out the ICE and replace it with an electric powertrain in order to produce its first EV. Local product adaptation is a tool used by global OEMs that tailor the product for emerging market needs without making major modifications of the product itself, but at least tailoring vehicle styling to emerging consumer tastes. Research collaborations allow to fast track new technologies that OEMs currently do not have in-house (e.g. battery technology for EVs). Modularization refers to the concept of creating standardized vehicle components or even systems that can be used in multiple vehicle lines or even brands (VW has mastered this concept combining more vehicle brands under one parent company than no other). Well-to-Wheel optimization is critical for developing zero emission transportation. It not only takes into account the emissions from tank-to-wheel, but also the energy source and related emissions from well-to-tank. Total system integration refers to a holistic NPD concept utilized by German premium OEMs that need to
manage highest complexity in their NPD approach. Social networking enables both NPD and vehicle commercialization through enhanced communication and knowledge sharing between functions.

5.5. VEHICLE CONCEPT PHASE

This section represents the initial phase of the automotive NPD for a specific vehicle platform by translating availability of new technologies, competitor benchmarks, stakeholder needs into a vehicle concept specification. The overall product portfolio influences the choice of product segment. Another aspect is the sales volume plan as any new vehicle project is based on a specific volume forecast for the target segment. This will support the business plan for the upfront R&D and tooling investment that needs to be amortized over the product life cycle. The core steps of the concept phase are: (i) technology selection; (ii) stakeholder needs mapping; (iii) derive supply-demand forecast derivation; and (iv) concept specification finalization. The first step comprises the selection of technologies/innovations that the new product line should have based on the targeted vehicle segment as defined by the NPD portfolio strategy. For example, some carmakers want to ensure that new product features or innovations are launched in the high-end models prior to launching them in the entry level segment. After that, the initial selection is translated into a list of requirements that the vehicle must fulfill (e.g. engine type/power, max speed, compartment size, no of seats, etc.). Based on a concrete set of requirements, a market model is utilized to map vehicle characteristics and forecasts in the respective target markets. This will provide an initial sales volume projection, which is crucial not only for the overall business plan, but also for supplier negotiations and in-house parts economics (note that tooling and R&D expenditure need to be amortized over the life cycle of a vehicle). Lastly, the final vehicle concept specification is derived, which is a core milestone in the new vehicle project.
Fig. 5-3 Second level detail – IDEF0 A1 Conceptualize vehicle
The author’s research, based on literature review and expert interviews, shows that emerging market OEMs, particularly in China, adapt the concept phase based on their specific setting (for example almost omitting the concept phase as vehicle concepts pre-exist from their foreign JV partners). While some papers suggest that China already has indigenous innovation [45]-[48], expert interviews and study examples from selected automotive OEMs suggest that the “clone, plug and play” concept remains predominant among Chinese OEMs. As seen from earlier discussions, Chinese OEMs have risen from a system of SOEs, where universities conduct basic research and OEMs traditionally received new IPs virtually free of charge. Another example that supports this argument is that SOEs and private OEMs primarily source their technology via foreign OEMs, as the JV partner that provides free vehicle concepts [18] as part of the JV agreements. At best vehicles are adapted for local market needs in the design phase and tap into local supply chain for cost benefits if possible. While the Indian car industry has a different regulatory setting for localization, a similar situation exists. Here, the author’s action research has helped to come up with such examples.

5.6. VEHICLE DESIGN PHASE

This phase essentially translates the concept specification into a validated design specification for the overall vehicle program and its key components. Different methodologies are utilized to optimize this activity such as modularization and so forth [42], [43]. These are typically applied during the design of the vehicle architecture and consequently the design of key components. Key components split the vehicle in sub-systems such as body-in-white (BIW), engine/powertrain, electric/electronic architecture, interior & exterior components. Some of these sub-systems are made in-house, while others are specified and then designed and manufactured by suppliers. Another element of the design phase is the production of the in-
house sample parts. For example, BIW or engine systems remain part of the OEM’s in-house value chain. Here, early ordering of the long-lead items with precise tooling requirements is crucial to keep the overall NPD timeline. Consequently, the first vehicle feasibility based on real parts and components is created that allows a refined validation of the overall vehicle design. The vehicle design and specification validation is the result of the design phase. The following figure illustrates the design phase in its full scope as described in this section.

Fig. 5-4 Second level detail – IDEF0 A2 Design vehicle
For illustration and explanation purposes, the author argues that global OEMs trying to tailor their product lines to emerging market needs are not re-creating vehicle designs from scratch, but are adapting the existing product designs. For example, to suit Chinese consumer requirements, a European mid-sized or even entry level sedan would be modified with a long-wheel base for the Chinese market. This simplifies the design phase significantly, as existing designs are either de-contented or adapted in one way or the other for local market needs. On the other hand, the business case must still be there to justify the incremental tooling investment for the body in white parts for example. Other examples are language adaptation or compliance with regulatory requirements from an emissions and safety perspective that will lead global OEMs to simply adapt existing product specifications instead of re-designing a new vehicle product. Examples of capabilities M2 are rapid prototyping, modeling, tool-building and the facilities to do so. Again, the author’s experience has been leveraged to provide such examples.

5.7. VALIDATION PHASE

Essentially this phase involves the validation of the vehicle design with regard to its practical feasibility for mass manufacturing, type approval and eventual commercialization. In principle, it consists of two parallel activities: tooling, parts approval, prototyping, testing and type approval on one hand, and production concept completion and final cost calculation on the other. The author can find no differences in terms of how emerging or global OEMs adapt these steps as these are essential requirements regardless of design and target market. In other words, irrespective of competitive pressures, OEMs must validate their designs as a prerequisite to commercialize their products. Also, OEMs need to conduct type approval for the respective target markets in order to comply with regulatory
requirements. The following figure shows the corresponding IDEF0 model, which is part of the overall methodology.

Fig. 5-5 Second level detail – IDEF0 A3 Validate vehicle
No specific tools are highlighted that could help coping with new competitive pressures other than the experience of utilizing the tools. The mentioned tool examples such as DFX (Design for Assembly/Manufacturing) methodologies or PPAP (Product Parts Approval Process) are no longer state-of-the-art and have been in practice for decades across the globe. On the capability side, experience in implementing certain process steps remains critical for any car maker to develop and manufacture new vehicle products.

5.8. CONCLUSION

In summary, the author introduces an emerging methodology for New Product Development in the automotive industry. An IDEF0 model describes the various stages in the process. Every IDEF0 node has been linked to references from the literature. Also, the author has developed a set of tools that help car makers to leverage the methodology while trying to cope with new competitive pressures. Here, the focus has been clearly the Chinese and Automobile industries. Some examples on how these can be applied are shown in Chapter 6. The emerging methodology consists of three core phases: 1. Vehicle conceptualization, 2. vehicle design, and 3. design validation. These stages represent the essentials of any NPD project in the automotive industry. Nevertheless, the author provides also an overview of how these stages are embedded in the extended enterprise system with close relations to strategy, marketing, sales and manufacturing departments as well as partners. Detailed diagrams are shown for every phase of the development of new vehicle products. Insights on specific tools and capabilities needed are provided in order to cope with new competitive pressures in the automotive industry.

During the course of this research the author developed an emerging methodology for the automotive industry by highlighting the critical steps in automotive NPD and by providing a toolbox that allows coping with new
competitive pressures. The focus has been Chinese and German automobile industries. The emerging NPD methodology as developed during this research:

- combines some of the existing tool sets;
- builds on new tools specifically addressing new competitive pressures such as emerging markets or zero emission requirements;
- makes adaptations that are specific to the automobile industry,
- leverages IDEF0 modeling to describe the methodology (enabling stage-gate and concurrent principles to occur in the same process); and
- provides a tool box that allows OEMs to cope with new competitive pressures in the industry.

The benefits of the emerging NPD methodology and its associated NPD toolbox are the following:

- better tailoring of vehicle products to emerging consumer needs;
- coping with zero emission requirements;
- smoothly integrating suppliers that might take a larger involvement in the automotive value chain; and
- improving overall competitiveness in an environment with many new entrants from emerging markets

In short, the emerging NPD methodology enables car makers to cope with new competitive pressures in the automotive industry as outlined at the beginning of this research.
CHAPTER 6  EMERGING AUTOMOTIVE NPD METHODOLOGY APPLIED

6.1. INTRODUCTION

After the introduction of the emerging NPD methodology in Chapter 5 and highlighting in Chapter 4 the approach undertaken in order to validate the emerging NPD methodology, this chapter is about illustrating the applicability of the methodology through multiple case examples. The author has developed those illustrative examples based on his real world industry experiences and time spent in China, the United States and multiple European countries as well as the inputs received from the various expert interviews (in some cases going back to the same interviewee several, once prior to developing the emerging methodology, once it was developed and then to go over its applicability in practice). While overall, the case examples are not a result of implementing the methodology by a car maker, they represent, however, a valid verification of how the methodology can be applied and its implications based on the author’s research from various expert interviews. In this section, there in total four cases, with linkage to the new competitive pressures in the automotive industry, with which the author illustrates the emerging automotive NPD methodology and its applicability into practice.
6.2. CHINESE OEMS DISRUPT THE CONCEPT PHASE

The author’s research, based on literature review and expert interviews, shows that emerging market OEMs, particularly in China, adapt the concept phase based on their specific setting. While some papers suggest that China already has its pure independent innovation [45]-[48], expert interviews and studied examples from selected automotive OEMs, however, suggest that the “clone, plug and play” concept remains predominant among Chinese OEMs. As seen from earlier discussions, Chinese OEMs have risen from a system of state-owned enterprise (SOEs), where universities conduct basic research and OEMs traditionally received new IPs virtually free of charge. Another example that supports this argument is that SOEs and private OEMs primarily source their technology via foreign OEMs, as the JV partner that provides free vehicle concepts [18] as part of the JV agreements. At best, vehicles are adapted for local market needs in the design phase and tap into local supply chain for the best cost benefits if possible. While the Indian car industry has a different regulatory setting for localization, a similar situation exists. The author illustrates the highlighted example in the following figure.
Fig. 6-1 Chinese OEMs disrupt the concept phase
As described earlier, Chinese OEMs often completely omit or pass by the concept phase and commence directly with the design phase. This has multiple reasons: on the one hand, Chinese OEMs receive vehicle concepts and part of the design via their foreign joint venture partners. On the other hand, Chinese OEMs may obtain vehicle concepts via design institutes that are part of the public R&D landscape such as universities or other public funded research institutions. Last but not least, the author has studied the so-called “clone, plug & play” approach as identified with multiple private OEMs in China (see Chapter 2.5 on emerging competitors in the automotive industry). In either of the options, the design phase represents the core step in the NPD approach. Here, existing vehicle concepts can be utilized along with deep knowledge of local markets. The design and validation phases benefit then from tools such as “clone, plug & play”, local sourcing, ‘manualization’ design, and localization. This helps to reduce the overall R&D expenditure for new vehicle projects versus a complete bottom-up approach. It also allows many cases to leverage proven concepts with less feedback iteration required. Nevertheless, the author came across one example, where a Chinese OEM primarily relied on their foreign JV partners to source new product developments. Here, difficulties associated with poor project management and coordination were a common issue in their product development department. The root cause of this problem, to a certain extent, was that the foreign partners have managed key product-development activities themselves, which slowed the transfer of critical skills to their Chinese partner. Consequently, the Chinese OEM excelled at localizing products for domestic tastes on the one hand (through restyling existing models to include rear-seat DVD players during the Design and consequent Validation phases), but is lacking of the broader product-development skills required to create entirely new vehicles from scratch.
6.3 GLOBAL OEMS ADAPT THE DESIGN PHASE

Another illustration example shows that global OEMs trying to tailor their product lines to emerging market needs, are not re-creating vehicle developments from scratch, but simply adapt existing product designs. For example, to suit Chinese consumer requirements, a European mid-sized or even entry level sedan would be modified with a long-wheel base for the Chinese market. This simplifies the design phase significantly, as existing designs are either de-contented or adapted in one way or the other in order to suit local market needs. To provide two examples, the Hyundai taxi in Beijing does not contain a vehicle airbag in order to save cost and weight. Or the localized Audi A6 uses lower grade injection molding plastic for the interior components compared to the global A6 from Germany (this is based on the author’s action research). On the other hand, the business case must still be there to justify the incremental tooling investment for the body in white (BIW) parts for example. Other examples are language adaptation or compliance with regulatory requirements from an emissions and safety perspective that will lead global OEMs to simply adapt existing product specifications instead of designing a new vehicle product from scratch. The following IDEF0 model illustrates this.
When global OEMs decide to penetrate an emerging market with a localized product, they will still undergo the concept phase. The concept phase is important to develop the overall business case for a new vehicle product as well as the concept specification. It is triggered by the OEM's overall product portfolio strategy defining vehicle segment and target
After strategic selection of the latest vehicle technologies available for series introduction and consideration of sufficient differentiation from competition, stakeholder needs are translated into overall vehicle requirements for this new vehicle product. The overall result of the concept phase is essentially the business case and the concept specification, which feeds then into the design phase.

In the design phase, the OEM does not need to re-develop new vehicle architectures or all key components but is able to leverage the existing platform with some adaptation of key components only (e.g. to comply with relevant localization requirements). Then, the design is simply refined by using local product adaption tools. This may include adapting the vehicle’s styling options tailored to local consumer needs, changes needed in order to comply with local regulations, but also changes that relate to product localization. This could mean de-contenting of certain parts and component as a result of the in-country industrialization. One critical aspect for global OEMs is to develop a local talent pool of engineers that are able to realize local product adaption in-country. The author learnt from interviews about those specific local skills that are needed for a company’s product development strategy and implementation expanding R&D capacity while keeping global costs down. Strong local centers are more likely to attract top local engineers, marketers, and designers; they can also bring along in-depth knowledge of the community and culture, as well adding to the overall capacity of global R&D operations. Traditional reasons for placing R&D in emerging markets – aim at lower costs and proximity to production – remain valid, but alone are not enough to support expanded R&D efforts. Instead, the importance of proximity to market and talent, when applied to individual product lines should determine when a company expands the role of offshore R&D (see the framework described in Chapter 3.3, Traditional OEM’s NPD Approaches). In summary, global OEM’s simplify the design phase while developing new vehicle products for emerging market penetration that allows to speed-up their go-to-market compared to NPD projects in traditional markets.
6.4. ZERO EMISSION NPD REQUIRES WIDER STAKEHOLDER INTEGRATION

After the illustration of typical approaches of emerging market OEMs and global OEMs trying to enter emerging markets, this section analyzes the wider stakeholder integration needed when it comes to zero-emission NPD. While relevant literature suggests an operational framework [40] for mature automotive markets regarding zero emission cars, or innovation through cross-industry integration of previously distinct modular technologies [41], the overall implications on vehicle NPD are analyzed in the following section.

To illustrate the earlier introduced well-to-wheel zero emission concept for the vehicle NPD, the contextual overview IDEF0 A-1 (see Figure 5-1 Contextual overview – IDEF0 A-1 Develop new vehicle product in the context of the wider enterprise and key stakeholders) needs to be considered. The key input here is I2: New Technologies. Whether for fuel cells, electric drive or any alternative propulsion technology, the key success factor is to have the core technologies ready for market usage. In many cases, carmakers find that their traditional core technology centered on the ICE is becoming less and less important. This, of course, drives the need for new core competencies e.g. around E/E engineering or hydrogen compression expertise. The actual vehicle development process is enhanced by well-to-wheel optimization (see NPD toolbox table). In addition, the production phase needs to reflect a green supply chain (Nunes et al. outline the implications for the automotive industry [34]). Finally, the process ‘use vehicle’ needs to be zoomed in as illustrated in the following figure for explanation purposes.
Here, it is necessary to have the right infrastructure provider depending on the vehicle technology that will act as an enabler for zero emission pathways. Whether it is the electric vehicle charging infrastructure with clean electricity from renewables or hydrogen fueling stations, infrastructure providers essentially determine the possibilities for complete zero emission pathways. At the same time, new business models are being introduced, such as car sharing concepts or other models where part of the energy storage is owned by a third party, to realize cost effective ways of commercialization. The following figure highlights some possible pathways from resource to transportation (‘well-to-wheel’) to illustrate the previous remarks around well-to-wheel optimization.
Fig. 6.4 Illustration of energy pathways for individual mobility concepts & transportation of goods.
6.5. SOCIAL NETWORK ENHANCED NPD IMPROVES OVERALL COMPETITIVENESS

Social network enhanced NPD is another aspect considered by the author, given the trend of increasingly globalized NPD team environments. Also, the need for wider stakeholder integration to realizing zero emission transportation is met with social network enhanced NPD. Various papers describe the importance of social network and related technologies (i.e. ICT technologies) in NPD activities [50], [54], including knowledge management activities [53], obtaining customer feedback [52] and China specifics [51]. The overall aim is to improve cycle time in the NPD process through more efficient stakeholder integration and means of communication. Different options regarding on improving NPD cycle time are described in the literature covering efficiency improvement through overlapping stages [56], applying NPD acceleration approaches through partner integration [55] and increasing communication to improve NPD performance [57] (one possibility to do so represents social networks).

In light with the various outcomes, both from literature and expert interviews, the emerging NPD methodology is presented in the following. Key highlight here is the Mechanism M1: Tools (see IDEF model A0; illustrated in the following figure). Based on the research, the author finds that there are two core systems: the development system and the CRM system. Both are in an evolutionary stage of social network enhancements.
Fig. 6-5 Illustration of social network enhanced NPD via development and CRM systems

The development system describes the NPD activity and is supported by a software tool in today’s OEM environments. It connects the
various functions directly involved in the NPD activity: product strategy, engineering, production engineering, procurement, supplier engineering, sales and marketing, by means of a software-based project management tool reflecting the company specific NPD standards. These computer-based development systems are company proprietary solutions in the automotive industry. In general, they allow managing the milestones of virtual project teams, integrating various functions along the NPD cycle including partners (i.e. supplier NPD teams, research partners, contractors, etc.). The ability to exchange via social networking (i.e. developer virtual groups with commenting or chat functions) allows for efficient NPD cycles of remote teams, cross functions and even integrates partners (such as suppliers, research providers or contractors). As mentioned earlier, emerging trends in the automotive industry require OEMs to integrate and work with their supply chain, and in some cases the infrastructure providers (downstream), to realize new energy vehicle concepts.

On the other hand, the sales and marketing function possess a typical CRM tool that gains more and more importance and captures from customer feedback, sales channel information (i.e. dealer management system) to overall sales and marketing programs every aspect related to the customer. Here, a variety of commercial CRM tools exist (i.e. Salesforce.com is the market leader) that incorporate social networking functionality up to the level of Facebook similarity. The ability to manage dealerships around the world, to efficiently capture new consumer requirements is crucial to achieving revenue growth in newly penetrated markets and tailor products to emerging consumer needs.

In summary, the described interdependencies of the core systems, incorporating the social network or collaboration function, enable OEMs to better cope with a variety of the emerging trends in the automotive industry thus enhancing overall competitiveness.
6.6. CONCLUSION

The author describes four examples to illustrate the applicability of the emerging NPD methodology. All four examples have been informed and confirmed by expert interviews as part of the validation process. The author’s own experience was leveraged through action research. The first example illustrates how Chinese OEMs are disrupting the concept phase to their R&D expense. This is an area to be considered by global OEMs in the future as they mature in emerging market localization and eventually can build on existing vehicle concepts that are reflect local customer needs. The second example is about how a global OEM penetrates emerging markets and hence simplifying the design phase as the core tool to be leveraged and the local product adaptation and vehicle engineering tapping into a pool of local engineers. The third example illustrates how to realize zero emission pathways by taking the whole transportation system into account. Last but not least, social network enhanced NPD allows to improve overall competitiveness along the up and downstream cycles of new vehicle products. In summary, the examples illustrate how to cope with new competitive pressures in the automobile industry and confirm the applicability of the methodology.
CHAPTER 7 CONCLUSIONS AND RECOMMENDATIONS

7.1. INTRODUCTION

This chapter summarizes the key findings from this research. It also provides a set of recommendations on how to apply the emerging NPD methodology. These recommendations are meant for global OEMs in order to help them in their journey to upgrading their R&D set-up so that they eventually are able to cope with new competitive pressures in the automotive industry. The focus has been the Chinese and German automobile industries leveraging the authors experience through action research. The benefits of the methodology are meant to better tailor vehicle products to emerging consumer needs, to cope with zero emission requirements, to smoothly integrate suppliers that might take a larger involvement in the automotive value chain, and last but not least, to improve overall competitiveness in an environment with many new entrants from emerging markets. The chapter is then summarized with an overall conclusion and provides directions for further research. These directions for further research are built around: 1. Expansion of the model for the entire road transportation system, 2. Collection of corresponding used cases from practice to further refine the methodology for the extended enterprise setting beyond just the R&D scope, which is the purpose and focus of this research.
7.2 THESIS SUMMARY

After identifying various types of innovation through an analysis of emerging trends in the automotive industry, the author proposes and validates an emerging NPD methodology that is able to cope with these trends also referred to as new competitive pressures in the automotive industry. Through literature reviews and expert interviews as part of empirical research, the author applies the new NPD methodology to a couple of case examples. These examples have been picked from the previously analyzed emerging challenges allowing for a deep-dive among multiple aspects of the methodology. Also, the author provides a toolbox for automotive NPD that enhances the methodology in coping with new competitive pressures in the automotive industry. It allows for the expansion from tank-to-wheel to well-to-wheel as part of the R&D framework of automotive OEMs and utilizes low-cost innovation approaches as part of vehicle system integration. In summary, this research analyses new competitive pressures in the automobile industry. These include: new consumer groups in emerging markets; zero emission requirements of existing customers; new competitors from emerging markets; and increasing dependency on suppliers. The research then shows how emerging and traditional car makers are applying distinct NPD tools to cope with these competitive pressures. These pressures require carmakers to react more rapidly when designing new models of automobile. New product development (NPD) is the core process used to develop synergy between customer requirements and the objectives of the carmakers to produce successful automobiles. This analysis has led to the development of an emerging NPD methodology consisting of concept, design and validation phases highlighting the interfaces to key stakeholders (such as consumers, infrastructure providers, suppliers, etc). The new methodology is informed and validated through a case study based approach that shows how emerging market players disrupt the concept phase, as global OEMs adapt the design phase while trying to comply with emerging automotive trends. A cornerstone of the new NPD methodology is the demand for zero
emission. This is demonstrated via new business models, while overall competitiveness is achieved through stakeholder integration facilitated by social networks. The findings of the research are confirmed by empirical research. Last but not least, the author concludes by giving recommendations as a result of the new NPD methodology that allows carmakers to better cope with changing requirements in the automotive sector. The following table depicts how the overall methodology and NPD tools are applicable to OEM groups addressing competitive pressures in the industry.
<table>
<thead>
<tr>
<th>Reference to IDEF0 node</th>
<th>Emerging NPD Methodology</th>
<th>NPD Tools (non-exhaustive)</th>
<th>Main competitive pressure being addressed</th>
<th>Applicability</th>
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<td>A0</td>
<td>Develop new vehicle product</td>
<td>Well-to-wheel Optimization</td>
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<td>Zero emission requirements</td>
<td>Emerging Market OEM</td>
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<td>Develop new vehicle product</td>
<td>Total system integration</td>
<td>Rivalry between existing players</td>
<td>Any OEM</td>
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<tr>
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<td>Develop new vehicle product</td>
<td>Social networking</td>
<td>Rivalry between existing players</td>
<td>Any OEM</td>
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<td>New consumer segments</td>
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<td>New consumer segments</td>
<td>Emerging Market OEM</td>
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<tr>
<td>A3</td>
<td>Validate vehicle design</td>
<td>Localization and local sourcing</td>
<td>Emerging competitors</td>
<td>Global OEM</td>
</tr>
<tr>
<td>A3</td>
<td>Validate vehicle design</td>
<td>Manualization to tap into the &quot;China Price&quot;</td>
<td>Emerging competitors</td>
<td>Emerging Market OEM</td>
</tr>
</tbody>
</table>
7.3  RECOMMENDATIONS – THE EMERGING NPD METHODOLOGY APPLIED

As outlined previously, innovation approaches of emerging market players are briefly summarized. Furthermore, recommendations to global OEMs are provided helping to identify steps in orchestrating their global R&D set-up to cope with the new competitive pressures, particularly focusing on designing new vehicle products for emerging markets.

Table 7-2 Overview of emerging market NPD tools

<table>
<thead>
<tr>
<th>NPD tool</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PolicyDrivenResearch</td>
<td>• Public policy decides the direction of research trends and related innovation</td>
</tr>
<tr>
<td></td>
<td>• Industry relatively weak compared to global benchmark and depended on government direction and funding</td>
</tr>
<tr>
<td>LowCostInnovation</td>
<td>• Focus on cloned solutions with leveraging low-cost manufacturing base</td>
</tr>
<tr>
<td></td>
<td>• Adopting existing solutions to suit low-cost manufacturing approach providing superior value at low price</td>
</tr>
<tr>
<td>Co-opetition</td>
<td>• Cooperation building with partners along the value chain to engage them in taking part of the development cost in return for assured business</td>
</tr>
<tr>
<td>IndigenousInnovation</td>
<td>• Delivering customer value by leveraging process innovation along the value chain and related partners</td>
</tr>
<tr>
<td>Institutionbuilding</td>
<td>• Building and environment outside the firms strategic competitive environment to lower costs</td>
</tr>
<tr>
<td></td>
<td>• Creating effective partnerships within the society at large</td>
</tr>
</tbody>
</table>

The above chart provides an overview of the identified approaches by emerging market OEMs when it comes to R&D and innovation. In summary, the disruptive patterns seen in China and India are breaking open
traditional value propositions by providing customer value at low cost instead of charging a premium. This effect then being linked to large market volumes and environments with a vast amount of first-time buyers enables the rise of emerging players. Eventually this will allow their presence in mature markets as well. Nevertheless, global OEMs can participate as well from the advantages of emerging markets when it comes to R&D by well defining their strategy to off-shore beyond just manufacturing. Recommendations for global car players' approaches to NPD are provided as follows.

Many items need to be considered when outlaying a global network of development centers, research hubs, sourcing and localization support offices. Most of the time, the question begins with what is core capability and non-core capability of an OEM. This may decide what element is transferred around the globe. Engineering outsourcing has commenced more than 40 years ago and has evolved ever since. To capture the potentials of doing so in an emerging market, has many levers such as the consolidation within the supply base that may cover complete systems/modules, optimization of capacity utilization and working capital management instead of investing (typical buy or make decision approach). Some OEMs have commenced to utilize engineering outsourcing in the field of niche variants. For example, utilization of a system supplier for development and manufacturing of various seat variants in India or utilization of off-shore research bases to conduct CAD designs. Another key motivation for R&D off-shoring: proximity to market, proximity to talent and lower cost factors are crucial when it comes to local product adaptation or complete off-shore module development used for global sourcing by reducing development costs along with the parts price itself. Examples range from engine calibration to adaptations of navigation and infotainment systems to suit local market conditions.

Furthermore, the local engineering talent base is critical to success. When it comes to talent-sourcing, the number of engineering graduates may
not be a sufficient indicator to judge the knowledge potential. For example in China, only a small portion of the engineering graduates can meet the requirements of international companies. One item that comes in to play regarding China are the English skills, which is obviously less developed than in India where English is a national language. Especially after recruitment, the local engineering teams need to be granted trust and to be integrated within the global R&D network. In many cases this is the most challenging task for foreign players who are generally afraid of knowledge drain. Nevertheless, the most effective way in capturing local trends, behaviors, needs and requirements is to enable local engineers’ voice in the overall organization. Markets that do not exist cannot be analyzed is not true when it comes to emerging automotive markets. Yet, the long term success of an engineering off-shore center highly depends on both, market size and growth potential of the local market, but also the future development of the region. This can be explained with the fact that developers that live among their target customers have much better insights in local behaviors and the interfaces between supplier and local OEMs. In addition, taping into cost advantages to compete with local players is to be considered. When it comes to the HR cost advantage, it needs to be considered that annual working hours may differ up to 30% in emerging markets and specific off-shore locations. Also, corporate taxation may differ and R&D cost is in some cases subsidized or tax deductible depending on the foreign players’ activities in that specific country. In some cases, the cost advantage is the only way to compete with local players by companies allowing complementary R&D strategies: one for high-end products in developed markets; one for dedicated products in domestic segments for emerging market penetration. Another aspect is intellectual property rights that are of key consideration when it comes to deciding what kind of R&D activities is transferred out of its original territory. Some technologies maybe critical and are kept at the HQ R&D location only; this leads to an approach where less know-how intensive technologies or previous generation models are capitalized with a longer life-cycle off-shore (for example transferring previous platform or engine technologies to off-shore). What is crucial to
reduce the risk of intellectual property rights violation is retention and promotion of core R&D staff members – often neglected by global OEMs that enter emerging markets with their NPD origination.

Throughout recent years, both OEMs and suppliers have invested in a tremendous production capacity building in China and India – mainly due to the urge of capturing the labor cost advantage while competing in local markets. Many suppliers use key levers to capitalize manufacturing activities in off-shore locations by using those hubs for both local and global demands by employing scale effects as well as by adopting the manufacturing processes. In many cases OEMs may have difficulties achieving a true cost benefit that focuses purely on their traditional tier-1 supplier bases that have moved to BRIC countries as well. Often, true cost benefits can be achieved by leveraging pure local suppliers. While trying to capture engineering cost advantages, and to fit product scope to local needs, global OEMs are given the following recommendations in attempt to exploit these opportunities. In other words, these are recommendation how to make sure to cope with new competitive pressures by successfully orchestrating R&D activities through the use of the emerging NPD methodology and associated toolbox.

1. Analysis of local market requirements and identify products and scope of items to be adapted for local market needs

2. Investigation if identified scope can be addressed by local talent pool, regulatory framework, resources and fit in global R&D matrix

3. Evaluation of true cost benefit by in-cooperating local partners and strengthening local management team

4. Assurance of proper interfaces within global R&D network to maximize efficiency
In short, tremendous net cost saving has been achieved for global players through the process of the R&D globalization and offshore activities transfer. Engineering cost reduction from BRIC counties is the next hype when it comes to localization – here, engineering localization enlarges the scope from just sourcing internationally. Simultaneously, proximity to market and talent are critical when it comes to understand local market needs for the necessary product adaptation to meet customer expectations of newly evolving target groups. As a result, local market needs can be captured and addressed in products that are able to compete with domestic players who disrupt traditional market share distributions by their own approach to innovation. Next steps are to consider emerging markets as a source for innovation – looking at the vast component pool for electric vehicles available in China for example.

While the provided recommendations primarily address on how to cope with emerging consumer requirements and up-raising competitors from emerging markets, they can be similarly applied to cope with zero emission requirements and smooth integration of suppliers that might take a larger involvement in the automotive value chain. By applying the emerging NPD methodology with its associated toolbox and reflecting the core steps to successfully orchestrating R&D activities, any global OEM is capable to better deal with new competitive pressures in the automotive industry. This is in essence the core purpose of what the emerging NPD methodology is aimed for.

7.4 CONCLUSIONS

No new vehicle development project will necessarily follow the methodology religiously. For example, unforeseen events or circumstances might require additional steps or skipping of certain activities. The intention is to provide a methodology for the automotive industry by highlighting the critical steps in automotive NPD and by providing a toolbox that enables
coping mechanisms for new competitive pressures. In summary, the benefits are: better tailoring of vehicle products to emerging consumer needs; coping with zero emission requirements; smoothly integrating suppliers that might take a larger involvement in the automotive value chain; and improving overall competitiveness in an environment with many new entrants from emerging markets. Many approaches have existed prior to this research, such as Cooper’s stage gate model or Concurrent Engineering with its multiple tools ranging from front-end loading to modularity principles. The emerging NPD methodology as developed during this research combines some of the existing tool sets, makes adaptations that are specific to the automobile industry, leverages IDEF0 modeling to describe the methodology and provides a tool box that allows OEMs to cope with new competitive pressures in the industry. The focus has been the Chinese and German automobile industries. The challenges currently faced by the industry cannot be met with traditional NPD approaches.

7.5 DIRECTIONS FOR FUTURE RESEARCH

There are two main levers for further research on the described NPD methodology: 1. To expand the model for the entire road transportation system, 2. to collect corresponding used cases from practice to further refine the methodology. The author has primarily focused on developing new vehicle products for both, the methodology and tool box as well as the description of the model with validated illustration examples. A possibility for extension can replicate the same research for all other elements of the road transportation system by, for example, focusing on: ‘manage & develop NPD portfolio strategy’ to reflect the wider portfolio approach in any NPD project; ‘produce vehicle’ as it interrelates with critical decisions in the NPD phase; ‘use vehicle’ as it more and more depends on the road infrastructure to implement new technologies. In other words, it would be an expansion to the extended enterprise beyond just R&D scope, which is
the focus of this thesis. Secondly, the identification of used cases from practice might be time consuming, but would help, however, deepen and expand a wider methodology focus on the whole enterprise value chain. Another aspect of expansion would be to deepen the understanding of emerging car makers outside of China and analyze how both American and Japanese car makers have coped in detail with the new competitive pressures in the automobile industry.
A.1. RENEWABLES: OPPORTUNITIES AND CHALLENGES

As seen in the previous section, Renewables play a vital role in achieving CO2 emission reduction targets through 2030. Looking at OECD, a country specific breakdown is necessary to adjust for local differences in availability of wind, water or sun to implement a Renewables portfolio.

The following case example assesses the situation for Great Britain. In line with the EU Renewables Directive, ambitious targets to reduce CO2 emissions have been set on a national level. It is expected that wind will bear the brunt of this objective. Despite uncertainties on the exact Renewable pathway, there could be as much as 50 GW of wind power required to reach CO2 emission reduction targets in Great Britain by 2030 [17]. With such amounts of wind power generation, future electricity markets will be highly influenced: unlike with thermal power stations, the electricity market will be dominated by large amounts of OpEx-insensitive wind power, along with highly intermittent output from wind farms.

A study and simulation on how electricity markets will behave in terms of pricing, patterns of wind based on weather correlation, operation schemes of various plant types and so forth has been conducted by Pöyry with some of the results discussed in the following [17]. Figure A-1 outlines a typical pattern as of today’s electricity market in Great Britain, where the dispatch of a thermal plant is dictated by the pattern of system demand based on a comparably small portion of Renewables in the energy mix.
Fig. A-1 Electricity price, power and intermittent generation in Great Britain, January 2010 (based on historical weather data from 2000) [17]

In comparison, the price chart of Figure A-2 shows, how the market spikes up reaching extraordinarily high levels in the last week of the month when the high pressure area moves in leaving insufficient wind. By the end of the month though, prices are spiking below zero as wind power dominates the market – simply due to different weather conditions. The bottom part of Figure A-2 shows the dispatch pattern by types of plant and an entirely different running scheme compared to today. E.g. Combined Cycle Gas Turbine (CCGT) plant’s operation becomes merely a response to the wind not blowing.
As a result, the running patterns of typical gas powered plants on the system are extremely irregular – their dispatch time may last from a few hours to a number of days and being dictated by the amount of wind.

While current electricity markets are driven by daily and seasonal changes in demand requiring different types of power generation with related costs to be dispatched, future electricity markets with large amounts of wind power will become dominated by the volatility of weather. This case example for Great Britain leads us to the next section on Smart Grids outlining possibilities how to mitigate the effects on electricity markets induced by a large portion of Renewables.

A.2. SMART GRID: ENABLER FOR ENERGY EFFICIENCY

Various definitions of a Smart Grid exist. For example, looking at Great Britain’s Electricity Network Strategy Group’s vision from 2009 [78],
a Smart Grid as part of an electricity power system can intelligently integrate the actions of all users connected to it - generators, consumers and those that do both - in order to efficiently deliver sustainable, economic and secure electricity supplies. In order to achieve that, a Smart Grid employs communication, innovative products and services together with intelligent monitoring and control technologies. The resulting benefits are to facilitate the connection and operation of power generation of all sizes and technologies (e.g. addressing the challenges as seen in the previous section). Simultaneously, demand side management needs to be optimized when dispatching various types of energy generation. This is achieved by an extension of system balancing into distribution and the home along other new load applications. This goes along with providing consumers with greater information and choice of supply. For example, smart appliances receive signals from smart meters that determine how they operate. Then, during peak periods, they can change modes or put off high-energy-consuming activities to times when more energy is readily available and costs are lower. Consumers can maintain their lifestyles with little or no disruption, while lowering energy costs. At the same time, utilities get lower peak-demand loads and increased consumption during low-demand periods – generating revenue from otherwise idle grid assets. Last but not least, a Smart Grid significantly enables to reduce the environmental impact of the total electricity supply system without making cut backs on reliability, flexibility, quality and security of supply [79].

The following figure outlines the growing complexity of applications and types of supply routes driven by Renewables. Smart Grid capabilities become inevitable for electricity markets, especially while looking into 2030 power generation scenarios (e.g. 450 Scenario).
After having analyzed the supply side, the following two sections give a review on the demand side and in particular transportation applications that are to become more and more relevant for grid applications. Here, wind, solar and biomass generation become welcome additions to the Smart Grid. By forecasting Renewable’s potential and storing excess renewable generation, integration of Renewables via a Smart Grid that acts as the link to enable efficient energy storage becomes possible.

A.3. REVIEW ON INDIVIDUAL MOBILITY

Traditionally, the transportation industry and in particular the individual mobility industry has been treated by sector specific requirements when it comes to emission reduction schemes. The efforts to reduce CO2 emissions from individual mobility are being focused primarily on car technologies such as energy management, light weight construction and
aerodynamics. With such a technology-focused approach, most cost-effective CO2 reduction cannot always be achieved [9], but as excluded from ETS few alternative options exist for the moment.

In the future, the effectiveness of technological measures on cars will increasingly depend on industries’ developments in other areas outside the automotive industry – for example the need for widespread availability of alternative fuels or the availability of an electric vehicle charging infrastructure [7]. The focus of the so-called Integrated Approach is not only on new car technology, but on all sources of CO2 emissions related to road transport. After all, that is what matters.

The Integrated Approach envisages cooperation with key players whose concerted efforts in car technology, fuels, infrastructure, traffic management, and driver behavior would contribute significantly to higher CO2 emission reductions being achieved on a more cost-effective basis. Over time, changing consumer preferences have had a market impact on CO2 emissions. These preferences were shaped by demands for larger, safer, higher and roomier vehicles. In many countries, these demands result from population shifts to rural areas that have created longer daily commutes to work or a general shift towards an increase in per capita car ownership (as seen in BRIC countries for example). In addition, users demand cars that include the latest safety features, often adding more weight [8].

Significant CO2 reductions have been achieved despite increases in vehicle size, mass, power, and capacity that have been influenced by changing customer preferences. Though, the 1998 self-commitment [7] of the European car industry could not be fully met. As a result, the European Commission and other policy makers around the globe are in the process of installing legislative CO2 emission measures in closed consultation with the car industry.
In Europe, the New European Driving Cycle (NEDC) target is aimed at 130gCO₂/km including further 10gCO₂/km reductions via complementary measures. A bonus system for so-called eco-innovations allows incentivizing car innovations. As a result, it becomes inevitable for car makers to push the roll-out of zero-emission vehicles.

In Chapter 2-6 on zero emission requirements, pathways of zero-emission transportation via electrification of powertrain were explored. This took into account the opportunity of bringing Renewables into play and therefore allowing for complete well-to-wheel zero emission pathways rather than just focusing on a tank-to-wheel optimization.

A.4. EXPERT INTERVIEW GUIDE

The following text was used to introduce the initial expert interviews. The questions evolved from the initial research phase to the final validation phase of the research findings. During the first set of interviews the author focused primarily on gaining an understanding of new competitive pressures in the automotive industry. This provided the basis for developing a set of tools to cope with these pressures as well as to better articulate the research gap. All this was achieved by asking questions about the core phases of the existing NPD process, interfaces with other stakeholders, employment of tools to cope with new challenges and so forth. During the validation phase, the interviews consisted of the author presenting the IDEF0-based emerging NPD methodology and associated tools for discussion and for refinement in some areas. This also allowed for the discussion of case examples from the perspective of the interview partners. As typical for expert interviews, the interview guide was not handed over to the interviewee to fill in the answers, but served as a guide for the interviewer to navigate through the interview without losing focus of the objectives. Nevertheless, it provided enough flexibility for the interviewer to adapt to the interview partners.
Interview Guide – Expert Interviews

New competitive pressures are unsettling traditional carmakers. These include: new consumer groups in emerging markets; zero emission requirements of existing customers; new competitors from emerging markets; and increasing dependency on suppliers. These pressures require carmakers to react more rapidly while designing new models of automobile. New product development (NPD) is the core process used to develop synergy between customer requirements and the objectives of the carmakers to produce successful automobiles. NPD has served carmakers well during an era of relatively stable competition with easily recognizable technologies and competitors. In a new area where technologies are changing rapidly and new competition is emerging there is a need for an emerging approach to NPD. This interview serves the research to better understand existing innovation patterns of both traditional and emerging carmakers. It also will help the author to develop and refine an emerging NPD methodology consisting of concept, design and validation phases highlighting the interfaces to key stakeholders (such as consumers, infrastructure providers, suppliers, etc). The emerging methodology is aimed at enabling carmakers to cope with new competitive pressures in the industry. The author uses a standard modeling language to illustrate the methodology. The interview also aims to discuss and analyze examples from real world with the interviewees. Consequently, these will help to develop recommendations for carmakers on how to better coping with new competitive pressures by using the emerging methodology and making use of its associated NPD toolbox.

Challenges

1. What are the key challenges your organization is currently phasing?
2. What are the competitive pressures you currently see in the automotive industry?
3. How do these challenges impact your NPD approach and portfolio?
4. How do you manage to comply with emerging consumer needs in your NPD portfolio?
5. How do you compete with upraising competitors relating to your NPD portfolio?
6. How do you manage to cope with zero emission requirements in your NPD process?
7. How do you cope with suppliers that take a larger portion of the value chain from an NPD perspective?

**NPD tools**

1. What are the NPD tools that you are currently using in your NPD process?
2. Can you please describe these tools and which purpose they serve in your NPD process?
3. What are the core capabilities that your organization needs to implement those tools?
4. Where do these NPD tools come from? Do you understand the origin of them and how they have been introduced into your organization?
5. What challenges do you currently see with these tools?
6. Are there any other NPD tools that you would like to highlight, but are currently not used in your organization?

**NPD methodology**

1. Please describe your current NPD process?
2. What are the main phases?
3. Do any of these phases happen in parallel?
4. What kind of feedback mechanisms do you have in place from one phase to the other?
5. How does your methodology enable you to develop the products your customers need?
6. How do you feel about splitting the principle phases into concept, design and validation phase?

7. What are the key interfaces, stakeholders and feedback mechanisms in this process?

Examples

If you were to develop a new vehicle program with this methodology and in the context of your company, how would you go about the following examples?

1. Develop a low cost car for an emerging market
2. Adapt an existing global platform for an emerging market
3. Develop a zero emission vehicle
4. Develop a zero emission mobility system from well-to-wheel
5. Integrate stakeholders in the development process (e.g. suppliers or infrastructure providers)

Thank you for your participation in this interview
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SUPERVISED MASTER THESIS PROJECTS
BY THE AUTHOR


BIOGRAPHY

Benjamin Thoma holds a joint MSc (2003) degree in Electrical and Electronics Engineering from University of Karlsruhe, E.S.I.E.E. Paris and University of Southampton and an MBA (2004) from Collège des Ingénieurs in Paris. Benjamin has more than ten years of industry experience from the automotive, energy and management consulting sectors working in Europe, USA and China.