Automotive Development Processes

Julian Weber

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Processes for Successful Customer Oriented Vehicle Development

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Foreword

The global crisis the automotive industry has slipped into over the second half of 2008 has set a fierce spotlight not only on which cars are the right ones to bring to the market but also on how these cars are developed. Be it OEMs developing new models, suppliers integerating themselves deeper into the development processes of different OEMs, analysts estimating economical risks and opportunities of automotive investments, or even governments creating and evaluating scenarios for financial aid for suffering automotive companies: At the end of the day, it is absolutely indispensable to comprehensively understand the processes of automotive development – the core subject of this book.

Let's face it: More than a century after Carl Benz, Wilhelm Maybach and Gottlieb Daimler developed and produced their first motor vehicles, the overall concept of passenger cars has not changed much. Even though components have been considerably optimized since then, motor cars in the 21st century are still driven by combustion engines that transmit their propulsive power to the road surface via gearboxes, transmission shafts and wheels, which together with spring-damper units allow driving stability and ride comfort. Vehicles are still navigated by means of a steering wheel that turns the front wheels, and the required control elements are still located on a dashboard in front of the driver who operates the car sitting in a seat.

However, what has changed dramatically are processes involved in vehicle development. What used to be solely the work of one brilliant engineer over several years is achieved today by a highly interlaced co-operative network of specialists coming from a variety of disciplines. The process of vehicle development has become a complex interplay of decentralized sub-processes which are steered on a relatively high level. Even though this has been the dream of automotive development managers for years, there is no such thing as a completely detailed process model. On one hand, if there were one, it would be out-of-date the day after it was completed. On the other hand, on the operational level, real vehicle development "happens" to a certain extent according to individual experience, preference, and current necessities, rather than following a meticulously detailed plan. Even at the most efficient carmakers in the world, it is, to a surprisingly high extent, an ad-hoc process. After all, automotive development is about people.

It is that twofold challenge, to both technically integrate separate components to create a complete vehicle, and at the same time to orchestrate the cooperation of thousands of people from different companies and different professional, cultural and social backgrounds, which makes automotive development so challenging and fascinating. The graduate course in Automotive Development Processes which I have had the opportunity to teach at Clemson University's International Campus for Automotive Research (ICAR), and which is the basis for this book, focuses on two topics: first, the realization of customer relevant vehicle characteristics, and second on the people involved: their personal objectives, their way of thinking and their interaction. I hope this book reflects and summarizes all of the fruitful discussions I have had with automotive experts from the most diverse areas, as well as my own personal experience gained over many years in the field of product development.

In this sense, this book is a personal report rather than a manual for vehicle development. It immerses the reader in the wide range of automotive development processes: from project milestones down to virtual collision checking; from product strategy to production and service integration; from agility to sustainability; and from E/E architecture to embedded software. My intention is to make the reader familiar with the entirety of what people really do in contemporary automotive development, rather than to discuss technical details in-depth. For example, for a passive safety engineer, the chapter on passive safety might only reflect his or her basic knowledge, but by reading through other chapters he or she can gain insight into the processes and the driving forces of neighboring departments and eventually get a better understanding of his or her job in the global context of automotive development.

Compared to other publications on automotive development, the approach followed in this book reflects a customer's rather than an engineer's point of view. It is my strong conviction that in automotive development, customer relevant vehicle characteristics must steer the concept and components, not the other way round. If eventually functions and properties such as agility, passive safety, cabin comfort or even cost suit the customers' requirements, the underlying technical solutions, such as the chassis concept, are of minor importance.

I hope that this book will help managers, specialists, consultants, analysts, students or anyone else interested in the field of automotive development, to better understand the overall process of motor vehicle development; and to recognize the technical and human relationships, dependencies and conflicts between the different sub-processes and the people involved. And lastly, I hope to share my fascination for this exciting profession.

Munich Julian Weber

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Additional Remarks

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Chapter 1
Vehicle Development Projects – An Overview

Abstract Vehicle development projects may range from a solitary model to a comprehensive model line with multiple variants and derivates, or from a simple facelift to a complete redesign. In any case, development follows a well-planned *product evolution process*, the so-called PEP. The PEP is the core process that transforms the strategic vision of a car into the reality of the first customer vehicle.

1.1 Categories of Vehicle Development Projects

The industrial development of motorized vehicles is usually organized in projects [1]. Such vehicle development projects vary greatly in terms of required technical content, financial effort, and length of time. The main parameters that drive the required effort are:

- Design level
- Design content
- Innovation level
- Number of options

1.1.1 Design Level

The design level of a vehicle development project describes where the project starts and thus determines the required effort. In order from high to low effort, the usual design levels are:

- *Complete redesign.* Starting from scratch, both concept and components are newly designed. Standard and carry-over parts are used only in non-visible areas. As an industry-wide rule, the life cycle of a car is seven years, so models are typically redesigned every seven years. Redesigns require the biggest effort for planning, designing and testing and thus are the most costly development projects.
- *Derivative design.* Redesigning a car based on an existing platform and system architecture (see Sect. 5.2.4). While parts and systems are reused to minimize development and production costs, the customer should - at least at first

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sight – not be aware of any commonality between the base vehicle and the derivative.[1]

- *Variant design*. In contrast to derivatives, *variants* visibly build a family of cars (see the variants of the BMW 3 Series in Fig. 1.2). Usually, alternative body types such as coupe, wagon or convertible are derived from a sedan. In addition to platform and architecture, parts of the body and exterior trim as well as interior components are carried over from the base vehicle. The effort required for designing a variant largely depends on whether the variant was already planned as a member of a model line during the design of the base vehicle (see Sect. 1.2.2).
- *Model updates* are minor design changes intended to raise the value (and thus the retail price) of a model after the first half of its life cycle. Usually, these changes include exterior trim parts (the reason why a model update is also referred to as a *facelift*), interior trim or new colors and options. The target is, to achieve a newer and fresher look-and-feel at the lowest possible development cost.
- A *model year* project summarizes changes required for cost or quality reasons. These changes are typically collected over a year and brought into production after the summer production shutdown. This allows minimal interruption of series production and the possibility to change production equipment accordingly if required.

1.1.2 Design Content

Another parameter that steers the complexity of a development project is the required design content. The more and the more complex functions the new vehicle offers to the customer, the more effort has to be put into design, evaluation and validation. Relative to the base vehicle, the usual indicators for design content include:

- Number of parts
- Number of electronic control units (ECUs)
- Number of lines of vehicle software code

1.1.3 Innovation Level

While technical innovation is one of the main factors that make a vehicle attractive to potential customers, their development increases not only design work, but

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[1] As an example of a derivative project, the body and interior of the current BMW X3 were all newly designed by Magna Steyr, re-using most of the drivetrain, chassis and lower body parts of the existing 4×4 BMW 3 Series.

especially testing effort on both the component and vehicle level. As no knowledge based on past is available, systems must be evaluated broadly. A higher number of problems can be expected that have to be solved later during the development process.

An example is the front body structure of the current BMW 5 Series. In the previous model, the front body was a pure steel design. Stamped parts of different steel grades were spot-welded together – a well known process with lots of data available describing operational strength, corrosion behavior, crash worthiness, aging characteristics etc. Evaluation of this design is more or less a standard procedure. The current 5 Series however is equipped with a front body structure that is composed of steel parts, aluminum parts, cast parts and plastic parts which are spot-welded, laser-welded, glued, or riveted together. This highly innovative solution required extensive – and thus costly – testing to ensure safety and functionality in every possible driving situation and durability over the whole vehicle lifetime.

1.1.4 Options and Country Versions

The major driver for complexity and thus for evaluation effort is the number of options offered in a vehicle. Premium brands typically offer the broadest set of freely combinable features to enable the customer to configure the car exactly to his or her needs and desires. While additional options might contribute to customer satisfaction and trigger the decision to purchase, they exponentially increase the required testing effort. For the new 2009 BMW 7 Series e.g., over 200 different options can be selected and combined – in addition to 12 different exterior colors and 12 different trim colors. This creates – theoretically – 3.5 E30 possible vehicle configurations, each of which should be geometrically and functionally evaluated to ensure 100% reliability.

The first approach to reduce complexity from options is to bundle them. If, for example, three levels of stereo systems (none, low, high) and three levels of navigation systems can be selected, then there are nine design combinations for these features. As the take rate for combinations of high stereo with none navigation or no stereo with high navigation is normally very low, it might make sense to offer only three stereo/navigation bundles: none/none, low/low, high/high – thus saving evaluation effort for six combinations.

A strategy followed by some Japanese *original equipment manufacturers* (OEMs) is to evaluate only the most frequently selected 20% of possible combinations, which typically represents over 95% of the vehicles ordered. If a customer selects a configuration that has not been evaluated before, it is then evaluated immediately – leading to a slight delay in delivery time for this vehicle. With this Pareto-approach, the full scale of independently combinable options can be offered while evaluation effort is greatly reduced. For a few customers however who order rare vehicle configurations, the wait for their vehicle's delivery can be very long then, because part of the vehicle's development is only started after their order is placed.

In addition to the options, legislation in different markets requires country specific versions. Acceptable emission levels, crash standards, and safety features differ especially between Europe, the U.S. and Japan (see Sect. 7.1). The country version that requires the biggest modification is the right hand drive which is mandatory e.g. in Great Britain, South Africa and Japan and induces variant parts for body, chassis, steering, dashboard, interior trim, harness etc. OEMs selling internationally usually offer three versions of their base cars: *Europe*, *U.S.* and *Right Hand Drive*.

1.2 Platforms and Model Lines

An established approach to develop more cars faster and at lower cost is the use of components in multiple different vehicles or platforms. Sharing standardized building blocks e.g. for electronic components, chassis systems or engines over several variants, model lines, brands or even OEMs lead to:

- Reduced costs and time required for component design and evaluation
- Reduced demand for tooling and equipment, including reduced costs and time required for design, manufacturing, handling and maintenance
- Increased vehicle quality through usage of mature and well-known components

Application of building blocks relates mainly to non-visible or non-differentiating areas of the vehicle. Two common strategic approaches for concentrated re-use of components are platforms and model lines.

1.2.1 Platforms

A platform[2] is a shared set of components common to a number of different vehicles which may also belong to different brands. The target is, to get maximum differentiation between the cars of one platform while sharing a maximum of parts. Most niche vehicle projects such as roadsters or sports utility vehicles (SUVs) would not be economical without reusing an existing vehicle architecture [2].

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[2] Originally, a platform was a chassis that was engineered for one and then reused for another car. For example the chassis frame of the Volkswagen Beetle was reused for the Volkswagen Karmann Ghia in 1954.

Probably the most consistent platform[3] strategy today is followed by the Volkswagen Group: The so-called Golf-platform is shared by 4 different brands and a total of 13 different models[4] and includes most parts of the powertrain, steering and suspension as well as parts of the lower body and interior trim (see Fig. 1.1). Differentiation takes place by exterior body and interior trim parts. Interface parts that connect the platform to the model-specific body are customized. Some parts are only differentiated by the attached brand labels (e.g. steering wheel cover).

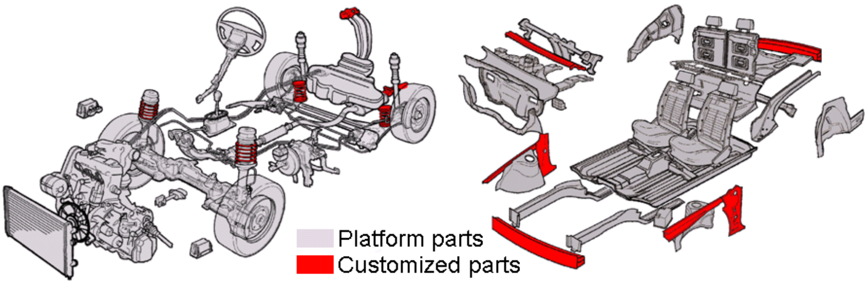

Fig. 1.1 Volkswagen Golf platform PQ34 (Source: Volkswagen)

1.2.2 Model Lines

While the commonality of vehicles sharing one common platform should not be immediately visible, vehicles belonging to one model line do also share exterior and interior parts, which makes them not only technically but also visibly members of one family. This resemblance can be seen e.g. among the variants of the BMW 3 Series model line (see Fig. 1.2).

In the past, model lines were created by first independently designing a base vehicle and then deriving variants. During the variant design, components which had been agreed as communal often had to be changed later on, spoiling parts of the intended savings in development costs. However, the full financial potential of a model line can only be tapped if all vehicles belonging to it and their shared parts and components are planned in advance. Basically this means, that concepts for all member vehicles must be ready and consistent before the first car to be launched goes into series development. A shared lower body structure for the basis sedan e.g. must be designed and proven feasible for coupe, wagon, convertible, 4×4 etc.

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[3] Engine, gear box, engine mount, front axle, steering gear, steering column, gear control, pedal system, rear axle, brake system, fuel system, exhaust, wheels, tires, front body structure, bulk head, lower body structure, rear body structure, seat frames, platform harness.

[4] VW Golf hatch, Golf wagon, Bora sedan, Bora wagon, New Beetle, New Beetle convertible; Audi A3, TT, TT roadster; Skoda Oktavia, Oktavia wagon; Seat Toledo, Leon.

even if those variants will be produced years after the basis. Equally, a consistent production strategy (which vehicle will be built at which plant) must exist at the same time.

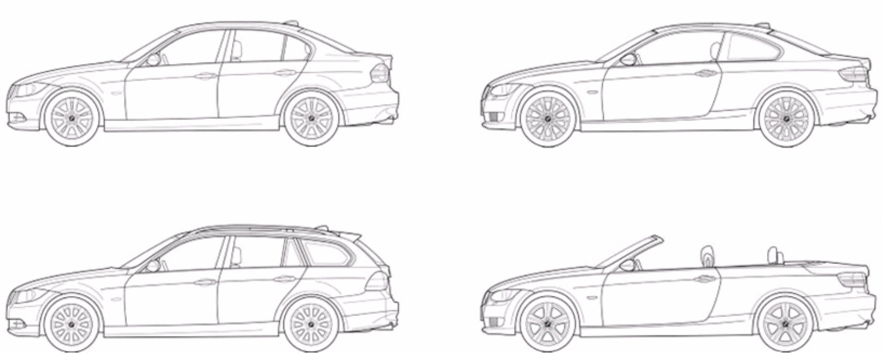

Fig. 1.2 BMW 3 Series family (Source: BMW)

1.2.3 Side Effects / Restrictions

While a consistent platform approach definitely offers advantages regarding development cost and time, it can negatively influence complete vehicle characteristics. If complete vehicle integration measures – e.g. to optimize the vehicle's dynamic driving behavior – may not change the platform components, optimization potential is limited.

From a complete vehicle point of view, a fine differentiation between true carry-over-parts (such as axle links or rims) and parts which should be tunable (such as dampers, engine mounts or tires) is the better solution. This more sophisticated approach requires in-depth experience regarding which parts and properties add up to which complete vehicle characteristic (such as driving behavior, cabin comfort, passive safety etc., see Chap. 7), but is the only way to optimize the product and keep development processes efficient at the same time.

1.3 The Product Evolution Process (PEP)

The PEP, also referred to as the *time-to-market process*, summarizes all activities for design and testing of the product as well as the set-up of production processes required for the manufacturing of the product. It is one of the three core automotive processes.[5]

In order to steer their vehicle projects, every OEM has their own detailed process model for the PEP, the "secret recipe" for their product development. These models define phases with milestones, specify the deliverables which are due at the respective milestones, and describe process chains as the participating players in the PEP and their roles. Although every corporate PEP is different (and usually strictly confidential), there are common patterns behind them representing an industry-wide accepted structure of vehicle development.

To discuss the PEP thoroughly, it must be regarded from different viewpoints (see Fig. 1.3): Seen from the timeline, we must distinguish the different phases of the PEP, from strategy to series support. From a process point of view, we must distinguish component design processes from integration processes and support processes. And applying the V-model of product development (see Sect. 1.3.3) we must always be clear whether we are in a phase of system design or integration.

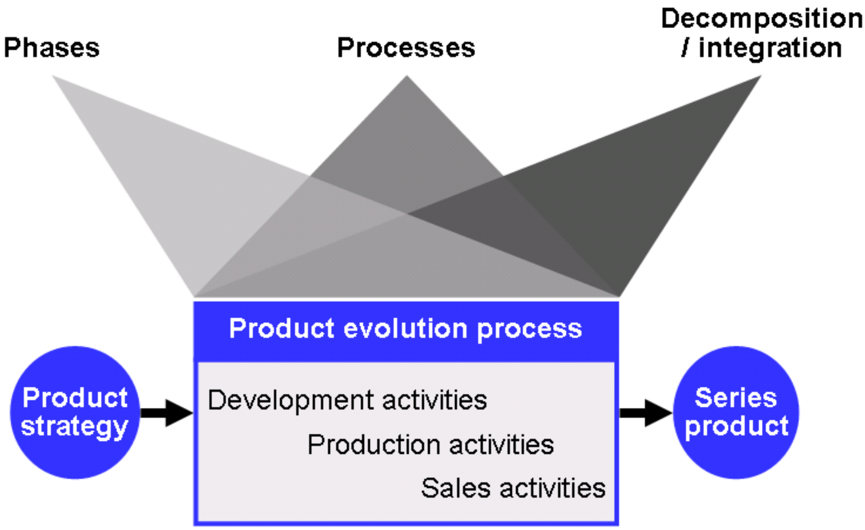

Fig. 1.3 Basic model of the PEP

[5] The other two core automotive processes are the *time-to-customer process* (that starts with the car being ordered by the customer and ends with the car being delivered to the customer) and the *time-for-service process* (that starts with the customer entering the dealership for service and ends with the customer leaving the dealership with his car in order).

1.3.1 Phases of the PEP

The first task in developing a new vehicle is the deployment of a *product strategy* or the general consideration of which cars a company should bring on the market at which point in time. Creating and updating this product strategy represents the continuous long-term planning process out of which distinctive vehicle projects or project programs are initiated. Figure 1.4 depicts how product strategy serves as a trigger for vehicle projects.

While product strategy is about complete vehicles, *pre-development* as another parallel continuous process deals with components and technologies (see Fig. 1.4). Here, innovative ideas taken from internal or external research, suppliers, partners or customers are concretized and evaluated regarding their technical and economic feasibility in products or related production processes. The decision which car will be the first to carry a pre-developed innovation is triggered by product strategy.

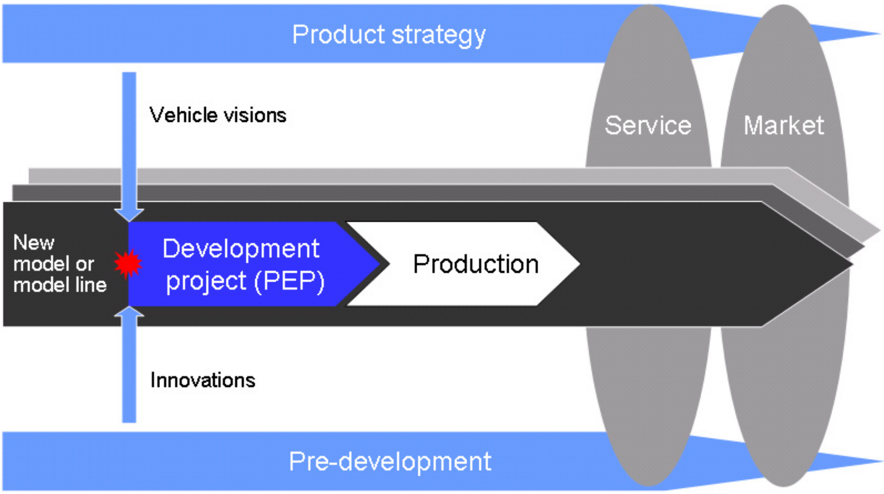

Fig. 1.4 Process framework of vehicle development projects

Both product strategy and pre-development are continuous processes and thus not project phases – even though they are often referred to as “strategy phase” or “predevelopment phase”. Both processes are discussed in detail in Chap. 1.

Even if naming may vary among OEMs, the PEP generally is divided into three main phases: Initial phase, concept phase and series development phase. Figure 1.5 depicts this general vehicle project timeline together with the respective milestones and general objectives. In addition, Fig. 1.5 shows series support and further development as a fourth phase after *start of production* (SOP). The distinct phases of the PEP are discussed in detail over the course of Chap. 1.

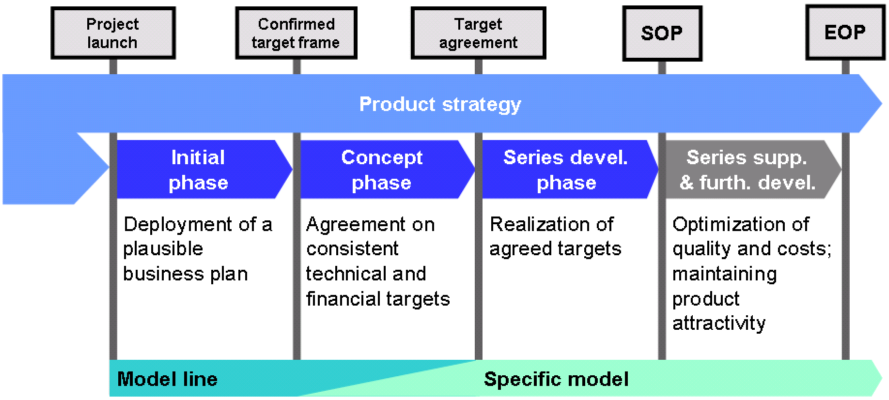

Fig. 1.5 Main phases of a vehicle development project

1.3.2 Processes of the PEP

1.3.2.1 Component Design Processes

Design *centers of competence* (CoCs) are home of the experts for specific parts and components. In a seat design CoC e.g., experts can be found for conceptual and series seat design, for testing, for cooperation with seat suppliers etc. By means of these *component design processes*, specifications are converted into series components by defining geometry, specifying material, planning a manufacturing process, and eventually releasing the component for series production and usage in a series product. With the release at the end of the process, the designer takes personal liability for the ability of the part to fulfill the specified requirements. On an upper level, most OEMs differentiate between the following six component design areas:

- *Powertrain design*: Engines, gearboxes, differentials, propulsion shafts, drive shafts, cooling system, exhaust system
- *Chassis design*: Axles, suspension, steering, pedals, wheels and tires
- *Body design*: Body structure (front, bottom, rear), outer panels, doors, hood, tailgate, fuel flap
- *Exterior trim design*: Front-end, bumpers, front/rear window, door system, trim parts etc.
- *Interior trim design*: Cockpit, trim parts, carpet, seats etc.

- *E/E component design*: Sensors, actuators, wiring and control units for driver assistance systems, information and communication systems, safety systems etc.

Organizationally, design areas are represented by design divisions, usually headed by a president directly reporting to the board of operations. Due to the geometric dependencies however, most OEMs have body and exterior trim design combined in one division. Other combinations are also possible.

Reporting to the presidents are their vice presidents, who manage the design CoCs. Within the chassis design division e.g., there might be one CoC for axles and wheels, one for brake systems and one for steering systems.

1.3.2.2 Complete Vehicle Integration Processes

Integration processes are used to define and develop the characteristics of the total vehicle. In contrast to the design engineers in the CoCs, integration engineers do not design any particular part, but rather evaluate the desired complete vehicle characteristics and feed their findings and technical recommendations back to the component processes. In doing this, integration processes steer the component design processes. The list below includes the six major integration processes.

- *Geometric integration* is the distribution and control of available space for all the vehicle's components. It embraces creation of the total vehicle package, allocation of package space to the component development CoCs, and monitoring of the geometric integrity of the complete vehicle by managing collisions and clearances (see Sect. 4.2).
- *Functional integration* is the validation of the functional characteristics of the complete vehicle from the customer's point of view, e.g. agility, cabin comfort, passive safety, etc. (see Chap. 7).
- *Systems integration* is the functional integration of the complete vehicle E/E system: Management of requirements, configuration and change management and integration of software with regard to development, production and service. Due to its criticality over the last decade, system integration is treated separately from functional integration (see Sect. 5.2.6).
- *Production integration* is the validation of the vehicle characteristics concerning production as well as the provision of the required production environment (see Sect. 8.1).
- *Service integration* is the validation of the vehicle characteristics concerning service, e.g. suitability for repair and maintenance (see Sect. 8.2).

1.3.2.3 Support Processes

To be able to develop products, design and integration processes need additional support processes. *Human Resources* has to provide people with the required skills at the right time and place in a development project. Especially the selection of the members of the project management team is crucial for the success of a development project. *Finance* has to check and provide budget and control project expenses to ensure cost stability. *Purchasing* selects capable suppliers for purchased parts or engineering services and contributes to the financial well-being of projects by analyzing and negotiating prices.

An important – though usually underestimated – task in a vehicle project is *internal communications*. Providing all members of the project team not only with the necessary information but also with internal news or success stories, internal communications can form a true team spirit and thus support successful project realization [3].

1.3.3 The V-Model of Product Development

Being the established process model in systems engineering (see Sect. 5.2), the V-model as shown in Fig. 1.6 allows a deeper understanding of the interplay of creative and analytical processes over the course of a vehicle development project. Starting with the specification of the desired complete vehicle characteristics, downward movement in the V-model (along the first leg of the V) denotes decomposition and specification - from complete vehicle requirements to system design and simulation down to parts specification, design and evaluation of parts. From here upwards (along the second leg of the V), the systems created out of the designed components are tested and validated against their specification in a hierarchical order - from components over sub-systems up to the complete vehicle. Design and validation of systems happens at the same level in the V-model [4].

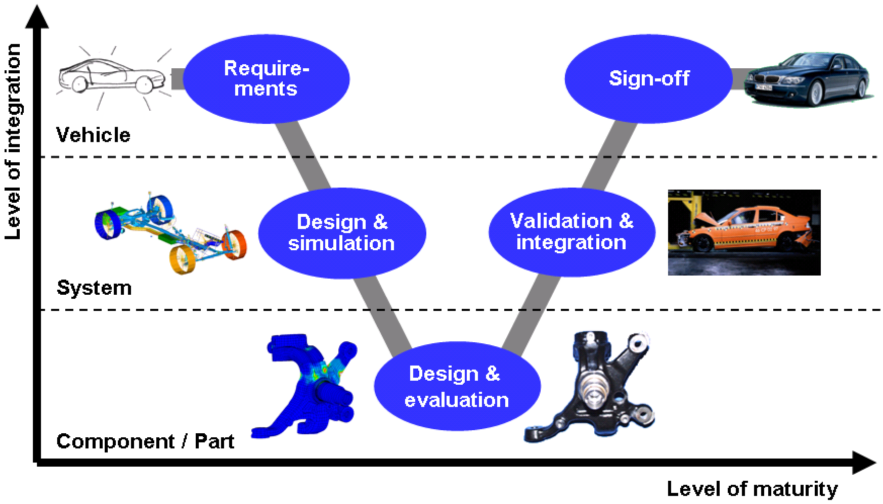

Fig. 1.6 Application of the V-model to the PEP (Source: BMW)

In contrast to IT-systems, automotive development requires several stages of prototype build and test at different points of product maturity. Each prototype build phase (see Sect. 3.3) represents a small product realization process itself. Hence, the V-model for automotive development shows subordinated Vs.

1.4 Vehicle Project Management

The task of Vehicle Project management is to organize and manage resources (such as money, people, materials, energy, space etc.) in such a way that the project is completed within defined targets (scope, quality, time and costs). It includes planning, controlling and deciding during product and process development. According to IEEE 1490 (2003), the nine disciplines of project management are [5]:

- Integration management
- Scope management
- Time management
- Cost management
- Quality management
- Human resources management
- Communications management
- Risk management
- Procurement management

As aforementioned, vehicle development projects are structured by milestones with defined deliverables attached. In contrast to other project management approaches, automotive project management usually sets milestones which require all processes engaged in the project to come to a consistent common state of product development.

A good example for a milestone and the respective project state is the start of a prototype build group. At the day set, the design CoCs must release a consistent set of parts that have been signed off by the integration processes. Also, production has to have their processes coordinated and matched to the released vehicle exactly on that day. Only this approach allows building prototype vehicles with the highest quality and hence the highest information value possible at this point in development.

With projects being structured by a series of these milestones, all activity is synchronized accordingly. For this reason, they are also called *synchro-points*. To ensure all sub-processes are on the right path between the synchro-points, they are structured and reviewed by *mini-synchro-points* (see Fig. 1.7).

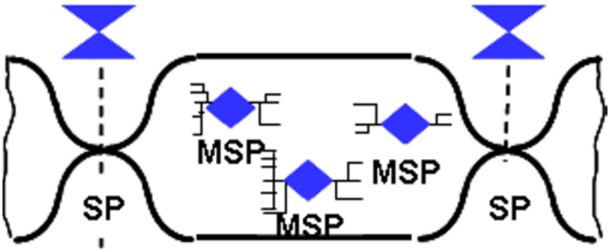

Fig. 1.7 Structuring of the PEP by synchro-points and mini-synchro-points (Source: BMW)

1.5 Aspects of International Development Projects

To remain competitive in an ever more global business environment, automotive companies increasingly work across geographical, socio-cultural and technical borders. Acting globally allows these companies to [6]:

- Increase turnover by selling and servicing their products
- Efficiently produce their products by utilizing local production technology and human resources
- Reduce transport costs and import duties by sourcing components locally
- Reduce risks from currency fluctuation by spending money in the same currencies as they earn it (natural hedging)
- Better design products to meet the local needs by involving local engineers

- Improve market position by expanding the range of potential suppliers and development partners

This strategic imperative for globalization in the automotive industry requires design engineers both at the *original equipment manufacturer* (OEM) and at the supplier sides to collaborate: to be able to sell cars in a new market, their compliance with local conditions and regulations must be considered and evaluated (a navigation system for instance, can only be tested in the country for which the car is developed and built). When launching production of a new car in a foreign plant, product process optimization requires local engineers to be involved in the problem solving process. And similarly, the local suppliers' engineers must be integrated in the vehicle development process executed at the OEM's engineering center. *Collaborative Engineering* is one of the keys to fully utilizing the business potentials of globalization. To make it work in reality, hindrances must be identified and dealt with.

The first of the two main hindrances are *socio-cultural differences*. Culture is apparent at first contact through language, clothes, habits, and then more pervasively through thoughts, unspoken assumptions, and values. In American-German teams e.g., the basic psychological differences are related to individualism versus collectivism, and to the avoidance of insecurity. Individualists focus on themselves, whereas collectivists put the group ahead of the individual. Americans are more individualists than the Germans. In terms of avoiding insecurity, Americans have much less need for security, and have more confidence in individual entrepreneurial thinking and personal abilities. Germans are formal, and want to use a systematic process, Americans are informal, and want to improvise. Germans want to take their time to reach a decision; Americans want an immediate result, even if based on a minimum amount of information.

These differences appear again in the language and communication process: In general, Americans are simpler, precise, informal, humorous, and friendly; Germans are more complicated, detailed, formal, reserved, and direct.

Finally, when one considers communication across the Atlantic, the distance creates barriers that have to be recognized and overcome. For instance, there are no chance meetings in the hallways to discuss a certain topic. The partners have to make the effort to establish the communication channels. Communication media does not lend itself to easily picking up the mood of the audience, and misunderstandings often occur because of the incomplete translation of thoughts into text using emails for instance. Thus, collaboration requires that the parties involved increase their communication efforts and are aware of the possible problems, and therefore take a proactive role in clarifying points, and asking for detailed explanations to avoid misunderstandings.

Aside from the "soft" socio-cultural differences, there are *differences in the business environment*: Technical, educational and legal facts that must be considered to ensure successful international cooperation:

- Technical border conditions: Climatic differences may negatively influence the transfer of a manufacturing process such as gluing; Electric power supply differs not only in voltage but also in frequency and stability; Professional education of workers might require more or less detailed description of how to do it in different countries.
- Materials and standard parts: Engineers in different countries prefer different materials – and have collected specific know-how concerning making, processing and designing with these materials. Although other materials might be also available, they usually are expensive and considered somewhat exotic. Standard parts such as fasteners, actuators, hoses, sealants differ in terms of size, geometry and specification/performance.
- Development standards: Material properties, tests, tolerances and manufacturing processes are specified by different standards, e.g. in Europe according to DIN/EN/ISO and in the U.S. according to SAE, ASTM.
- Legal background: An important boundary condition for international collaboration is the legal system providing the applicable laws. To ignore the peculiarities e.g. of the U.S. legal system can be extremely high risk for foreign companies, not only concerning product liability. Other fields of important legal discrepancies are patent law, health care or business taxation.

In summary, companies have to consider the various differences between the cultures, the technical and legal aspects of doing business, and must weigh the gains that may result from the collaboration against the overcoming of the hindrances to collaboration outlined above. On the other hand, collaboration brings forth the collective thinking process of people with different backgrounds and experiences. The richness of solutions is typically expected, and the tailoring of the products for the markets in which they are developed enhances market acceptance and penetration and therefore company reputation and market share.

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Chapter 2
Product Strategy

Abstract The basic and most important decisions of any automotive OEM relate to the question of when to bring which vehicle to the market. Even though there is no formula for guaranteed success, an analysis of cars that succeeded and cars that flopped in their respective markets leads to a list of minimum requirements that should be checked as part of the of strategic decision making process.

2.1 Cars that Topped and Cars that Flopped

The task of automotive product strategy is nothing less than to give the best possible prediction of which cars the customers will buy in the future. The best development processes can not compensate for wrong strategic assumptions. This makes product strategy the most important task in vehicle development and the driving force in corporate strategy. The answers product strategy has to give include:

- Which cars will customers buy in the future – and how many?
- What should the complete product portfolio look like in terms of brands, model lines, variants?
- Is it enough to continue and redesign or are new models or model lines required?

Viable predictions to these questions require comprehensive consideration of future boundary conditions such as:

- Customer needs: Will certain features such as high speed and dynamic performance still be important, when megacities grow and urban and suburban streets get ever more congested?
- Social acceptance: What will society think about cars with any kind of emissions? Will the whole principle of individual mobility still be generally accepted?
- Brand values: Will the current brand values still appeal to future customers?
- Legislation: Which laws and regulations will apply worldwide that might influence the purchasing decision or development, manufacturing and sales processes?

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- Corporate strategy: What is the long-term plan for the company regarding location, employees, technologies etc.?
- Competition: Which cars will the competition offer?

Automotive history is full of examples for cars which were eminently successful at their time or on the contrary just flopped. With the wisdom of hindsight, it is usually very easy to analyze the respective reasons. Analysis of these projects is important to be able to deduce the interrelations that lead to failure or success.

2.1.1 Tops

There are many definitions of what success means for automotive development: Number of styling awards, ranking in quality assessments or customer surveys, ROI etc. In terms of strategy however, the relevant question is not so much the detailed result of series development, but the coherence and consequent long-lasting attractiveness of the general vehicle concept. From the viewpoint of an OEM, a commonly accepted measure for the success of a vehicle concept is hence the number of units based on that general concept that could be sold over time. With this in mind, the five most successful cars in automotive history are the Toyota Corolla, the Ford F-Series, the Volkswagen Golf, the Volkswagen Beetle and the Ford Model T [1].

The first car that was manufactured on an assembly line, the Ford Model T started a new era of the automotive industry. 16,500,000 cars were sold from 1908 through 1927. The commercial success however stemmed from the new production approach that allowed an unrivaled price. In 1914, assembly time was only 93 minutes and the Model T was sold for $850 (and later even below $300) when competing cars were priced at over $2,000. The lead over competition was so big, that no advertising was needed for the Model T between 1917 and 1923.

At the end, the reason for its success became the reason for its end: Sticking to the same concept to allow fast and efficient production. By 1925, other cars offered much more comfort and style – now at competitive prices. The Model T lost its supremacy on the market and Ford discontinued production in 1927.

Another car that never really changed its initial concept is the legendary Volkswagen Beetle (see Fig. 2.1 top left). 21,529,464 units produced between 1935 and 1983 make it the fourth best selling car in history. Compared to its competitors such as Citroen 2CV, the Beetle had superior performance,[6] excellent handling and was still a low cost car both for purchase and for maintenance. Together with the unique body style, this made the Beetle a trendy and desirable car for generations of customers.

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[6] Max. speed 115 km/h (72 mph), acceleration 0–100 km/h (0–60 mph) 27.5 seconds; fuel consumption 7.6 l/100 km (31 mpg) with a standard 25 kW (34 hp) engine.

Fig. 2.1 Most successful cars ever: VW Beetle, VW Golf, Ford F-Series, Toyota Corolla (Sources: Volkswagen, Ford, Toyota)

In 1974, when popularity of the Beetle started to decline, Volkswagen launched their second big hit: The VW Golf (see Fig. 2.1 top right), which gained world-wide popularity through five redesign generations. Although the concept never was really accepted by the big American market, to date more than 24 million Golfs have been sold world-wide.

The success of the Golf is founded in providing a new concept in the compact class (water-cooled front-wheel drive, east-west engine, hatch-back) that was affordable for everyone, offered enough space for five passengers and baggage and still was sporty and considered cool. The Golf was so dominating in the compact class that it is still called the *Golf Class*. In Germany, people born between 1965 and 1975 are referred to as the *Generation Golf*.

While the golf never was a big selling car on the U.S. market, the Ford F-Series Pick-up truck (see Fig. 2.1 bottom left) has sold over 25 million units since 1984, solely in North America. The F-Series has been manufactured for over 5 decades and is now in the 11th generation, and has been the best selling vehicle in the U.S. for 23 years. The basis for this success is its high reliability gained by use of robust technical solutions, the huge choice of body and trim options and the affordable price.

Toyota introduced the Corolla (see Fig. 2.1 bottom right) in 1966. While styling initially was rather unexciting, the Corolla convinced its customers by quality and cost-effectiveness. Toyota has kept the car attractive now for over 40 years and completely redesigned each of the Corolla's nine generations. It was first in its class in almost every quality and reliability ranking. To date, over 35 million Corollas have been sold all over the world.

2.1.2 Flops

The reasons for the success of the top-selling cars listed above are manifold – and so are the reasons that lead to a vehicle not coming close to reaching the planned sales targets, commonly called a market flop. Again: Market success is much more than design quality! Some of these flops are or were technically brilliant car concepts that were just realized too late or too early, had wrong assumptions of future customer priorities set as a basis for design, relied too much on the attractiveness of innovations, or were even just poorly marketed. Four prominent examples of vehicles that were loved by the people who bought them – but from their manufacturers' point of view did not convince enough people to buy them – are the Ford Edsel, the Renault Avantime, the Glas 2600 and the GMC Envoy XUV.

The probably best-known and most spectacular flop in automotive history is the *Ford Edsel* (see Fig. 2.2 top left), which was manufactured by Ford Motor Company from 1958 to 1960. It is a good example, because it was not poor quality or concept but a series of circumstances that eventually led to failure. It was "the wrong car at the wrong time with an awkward name and was too big when economical circumstances demanded for smaller cars" [2].

An example of a car that was flawless and well-accepted by customers but still became an economic disaster is the *Glas 2600 V8* (see Fig. 2.2 bottom left). In 1966, the product strategy of Glas, well-known for designing the after-war Goggomobil in the 1950s, crossed the boundaries of its brand by designing the Glas 2600 V8, a technically brilliant sports car which was nicknamed "Glaserati" at its time. But the overall structure of the Glas company was not ready for cars at this high level. Production expenses grew too high and only a pre-series was built of the 2600 V8 when the financial situation of Glas was so bad that they were bought by BMW in 1966.

A more recent example is the *GMC Envoy XUV* (see Fig. 2.2 bottom right): Despite a highly innovative retractable roof, the XUV sold so poorly that production was discontinued after only 2 years. It was never really obvious, why customers more or less ignored this car.

The *Renault Avantime* (see Fig. 2.2 top right) was designed and built by Matra between 2001 and 2003. It had a radical and unique design, a mixture of van and coupe. Though other ambitious Renault designs at the beginning of the 21st century were very successful, customers did not appreciate the Avantime at all. Sales were extremely poor and the project became somewhat of an economic disaster. As a result, Matra went bankrupt and pulled out of the automotive production business in 2003. Renault decided to discontinue the Avantime – after only 8,545 cars were built.