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Categorization and integration of new and innovative materials in the development process of semi-finished products at the Dr. Ing. h.c. F. Porsche AG

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A project carried out on the Masters in Management Program, under the supervision of:
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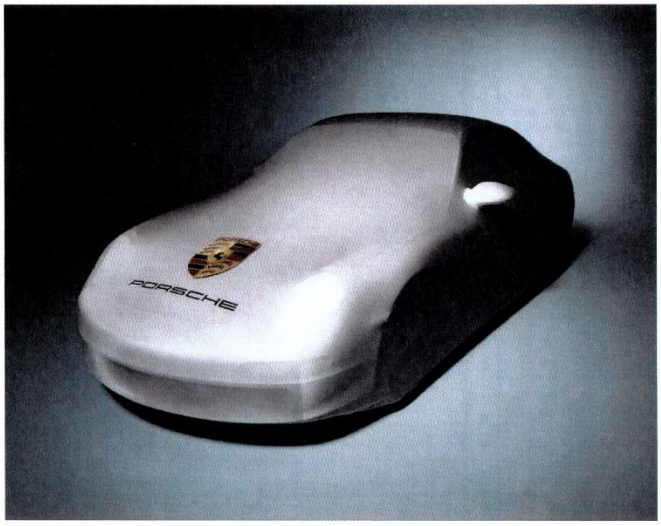
PORSCHE



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Abstract

This paper serves as a guideline on how to integrate new and innovative interior materials in the development process of semi-finished products in the automotive industry. Therefore automotive interior trends were researched and the interior development process of the sports car manufacturer Porsche was examined. Three categories of materials were created to allocate new materials with similar characteristics to. On this basis, respective processes for each of the three categories were designed to ensure a smooth integration of innovative materials for future projects. The paper shows that depending on the category, materials belong to, the development activities and durations vary.

Keywords

automotive industry; innovative interior materials; product development process; process optimization

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1. Introduction

1.1 Problem and Challenges

The current automobile industry is confronted with an increasingly dynamic and also complex environment. Traffic keeps becoming denser caused by over 1 billion cars on our roads today. Forecasts are even predicting a continuous growth of car sales and about 100 million cars to be sold by 2020 (Statista, 2016). This change is accompanied by a trend towards autonomous driving, which will highly impact the automobile industry. In the near future there will be no need to sit behind the steering wheel and focus on the roads anymore (Berman, 2016). Instead, customers will spend more time in the interior of their cars and hence put more focus on a nice and comfortable atmosphere inside (Berman, 2016). Customers want to be able to relax while being in the car. Moreover they want to be able to work from their car and be in close contact with the environment (Fuchslocher, 2016). While the exterior has been a critical factor for the purchasing decision in the past, the interior will become of significant importance in the future (Berman, 2016; Walter, 2014).

On top of that there is a rising awareness and sensibility for environmental issues of vehicles (Ghassemieh, 2011, p.370). Emission-free cars are facing an increasing demand due to the fact that customers feel a stronger sense for the negative effects vehicles have (Gebhardt, 2011, p.12). Thereby not only technical issues such as a combustion engine are in the focus. Especially in the automotive interior one can observe a trend towards sustainable and bio based materials (Brünglinghaus, 2014). The sensibility of customers for the materials applied has therefore a great impact on the choice of interior materials for OEMs[1] (Grand View Research, 2015).

In general, the interior development of the OEMs is living through a big change. Many new trends and innovations are introduced to the market and put pressure on the OEMs. In order to

[1] OEM (Original Equipment Manufacturer): "Producer or manufacturer of a complete end product (…) or a sub-assembly (…) used in an end product." (Business Dictionary, 2016)

fulfill today's customers' demands, it is essential for car manufacturers to keep up with new interior trends. Especially in the premium and luxury segment of vehicles these new trends have a major impact and relevance. Within the luxury segment, interior materials, besides fulfilling general demands on sustainability, durability or design, they need to fulfill aspects regarding the quality and value (Grand View Research, 2015).

Thereby this new movement is not only challenging in terms of identifying new trends and demands but also in terms of integrating new and unknown materials in the current interior development process of OEMs. New materials differ in their characteristics and features and may therefore also be different in their usage and handling. Semi-finished products afford more testing in the beginning of the development process in order to proof if they are suitable for the automobile interior usage at all. This can be a big challenge for OEMs. They need to find a solution on how to integrate new and innovative materials in their current process.

1.2 Objective

The objective of this work project is to propose a solution on how to integrate new and innovative materials in a current development process of semi-finished products in the interior. As an example from the industry, the leading luxury sports car manufacturer Porsche has been selected. When Porsche introduced its plug-in hybrid super sports car Porsche 918 Spyder in 2010, many new and innovative materials were applied for the very first time. It has been a flagship project for Porsche which however brought along various challenges, especially in terms of integrating new materials. In a few years Porsche will launch the first all-electric sports car, the Mission E, which will be the next flagship project for Porsche. It will once more revolutionize the market and include many new and innovative interior materials. Therefore it is of high importance for Porsche to have an approved process on how to integrate new materials in their current process. As a first step of this work project, new trends and innovative materials in the field of automotive interior will be researched and introduced. Up on this step, new

interior materials will be categorized in order to simplify the development of a process. The categorization is based on the outcome of interviews with experts from various departments. At the same time it will be closely looked at the current semi-finished product development process at Porsche, to find out, where new materials cause difficulties in the current established process. Based on these findings, a guideline will be developed on how to integrate new and innovative materials in the future in order to guarantee a smooth process and an on time start of production.

1.3 Company Introduction and the Color Matching Department

The company **Dr. Ing. h.c. F. Porsche AG** was founded in 1931 as Dr. Ing. h.c. F. Porsche AG, Construction and Consulting for Engine and Automotive Construction. During that time Porsche has solely been a design office. In the mid-1940s Porsche started to focus on the production of sports cars and became an automotive manufacturer with the type 901 being their first model, presented in 1963. Today, Porsche is the most traditional and successful manufacturer of sports cars worldwide. Besides its sports cars 911, Boxster/Cayman and its limousine Panamera, 50% of the manufactured cars are SUVs (Cayenne and Macan). Porsche's headquarter is located in Stuttgart-Zuffenhausen, including the production and engine works. A second production plant was opened in Leipzig in 2002 and is dedicated to the production of the SUVs and the Panamera. The R&D Center of Porsche is based in Weissach, including a test track and skid pad. In addition to that Porsche has locations in Sachsenheim (Spare Parts Depot), Bietigheim-Bissingen (Service Center), Ludwigsburg (After Sales) and regional sales offices worldwide (Porsche a, 2016).

Part of the R&D at Porsche is the development of colors and materials. The wide range of numerous colors and materials in the interior and exterior of vehicles demand a high level of coordination. Therefore the department of **Color Matching Surfaces** is responsible for the coordination and management of the color and material development and represents an interface between the design, procurement, quality management and material technology

department. Its main task is to ensure the equipment of vehicles with new colors and material in due time, until the start of production (Porsche b, 2016). This work project has been carried out at the Color Matching Surfaces department.

2 Theoretical Framework

In the following, the general definitions and the theoretical framework will briefly be outlined before the concepts will practically be applied in the succeeding parts of this work project.

2.1 General Definitions

2.1.1 Semi-finished products

Meinberg and Topolewski describe a semi-finished product as "… a material with a defined form, surface and condition." (Meinberg, Topolewski, 1995, p.241). Semi-finished products are the basis materials that are used to produce parts or modules (Meinberg, Topolewski, 1995, p.241). Taking the car seat as an example, the textile is a semi-finished product while the complete seat system is a module.

2.1.2 Master sample and Color Target

The master sample for the color of the interior semi-finished products such as for example textiles or foils is a coated decor plate. In exceptional cases it can also be a real leather sample. The plate / leather sample is measured by a colorimeter[2]. The measured value of the master sample that is the closest to the measured mean of all samples is the color target. This implies that all following materials that will be produced, must match the color (optic) of this one master sample. Afterwards all other materials (foils, plastics etc.) are developed according to this color target and are from then on a master sample for the optic (color) and haptic (surface) by themselves (Porsche d, 2016). The reason for the importance of master samples is, to ensure

[2] Colorimeter: "An instrument for measuring the intensity of colour." (Oxford Dictionaries, 2016)

that every single material which will be produced, is compliant with the color target of the master sample and guarantee a color matching in the end.

2.2 Interior Materials

More than 30 different materials are applied in the interior of a Porsche vehicle (Porsche b, 2016). Thereby they can differentiate in color, surface or quality. In the following the characteristics will be introduced which make a material suitable for automotive usage. Moreover the currently applied semi-finished products at Porsche will be presented and new trends in the automotive interior field be outlined.

2.2.1 Automotive Suitability of Materials

In order to be suitable for automotive usage, a material should have certain specifications and characteristics. Ghassemieh mentions the following four requirements in order to be qualified for the usage in an automobile: cost, lightweight, safety and recycling (Ghassemieh, 2011, p.365ff.). Explicitly for the interior however, a material needs to fulfill more requirements. On the one hand a material has to match customer demands. In particular it needs to meet the customers' expectations regarding an attractive design. The material surface has to be appealing to the customer. Furthermore convenience is of high importance. The customer needs to feel comfortable with the material in the vehicle interior and therefore it also needs to be valuable in order to convey a positive impression (Brünglinghaus, 2014). Nevertheless a material also needs to meet certain technical requirements. First of all it has to satisfy the requirement of functionality such as scratch or weather resistance. It also needs to fulfill the demand regarding its function and feasibility. Moreover the ergonomics of the material are important as well as its sustainability and costs (Brünglinghaus, 2014). Especially for Porsche, superior quality is of

high importance. Today, 70% of the ever produced Porsche vehicles are still on the roads, which can be ascribed to the surpassing quality of the vehicles (Porsche c).

2.2.2 Currently applied Semi-finished Products in the Automotive Interior

The individual semi-finished products can be clustered in the following main groups **[Appendix 1+2]**:

semi-finished product	characteristics	areas of application
leather	Variety of different leather qualities: split leather, embossed leather, nappa leather, natural leather, authentic leather	• dashboard • seats • door panel
coats	Different coatings: black glossy coating, black matt	• dashboard • center console • door panel • roof (headliner) and pillars • trunk and carpet • door panel • seats
foils	Foils differentiate by their surface and texture (different grains)	• dashboard • center console • door panel • roof (headliner) and pillars • trunk and carpet
yarns	Yarns are available in different qualities depending on their field of application and strain. They are used as functional yarns to hold textiles together but also as decorative seams.	• dashboard • center console • door panel • seats • trunk and carpet
textiles	Textiles are the biggest main group of the interior materials. Following textiles can be found in the interior: Alcantara, convertible hood textiles, carpets, belt straps, nets	• dashboard • center console • seats • restraint system • roof and pillars • trunk and carpet
decors	Various materials and surfaces are available: wood, aluminum, carbon, plastic	• dashboard • door panels

Figure 1: Semi-finished Products in the Automotive Interior (own figure)

2.2.3 Trends in the Automotive Interior

Every year many trends and new innovations are entering the market such as biological or lightweight materials. In the following, two of the main trends in the automotive interior will briefly be introduced. One of them is **sustainability**. Already today it is noticeable that customers put a high emphasis on naturally produced and sustainable interior materials. OEMs like BMW have recognized this trend in an early stage and so applies natural and sustainably produced materials in the interior of their electric car BMW i3 already. For the seats, BMW uses textiles that are sustainably produced out of 100% recyclable polyester, of which 34% are made out of old PET bottles (BMW, 2016) **[Appendix 3]**. This is a trend that has been derived from the fashion industry, where already a few years ago designers started to make clothes out of natural material (Köhn-Ladenburger, 2015, p. 32).

Another example for sustainable textiles is Piñatex, a leather which is made out of pineapple leaves (Ananas Anam, 2016). Until today it is mostly used in the fashion industry. However, first tests have been started to proof its automotive usability. The trend towards more sustainability is expected to boom massively in the next few years and will affect all segments of car manufacturers. But in particular for premium car manufacturers it will be a big challenge to manage the alignment of sustainability and luxury (Kapferer, 2010, p.40).

Moreover there will be a trend towards **intelligent light systems**. Light will not only be applied directly anymore. For example there will be self-illuminating yarns which can be used in seats or door panels and give indirect light to the interior. Also in combination with textiles and leather, lights will play an important role in the near future. With new light innovations OEMs want to create a relaxed atmosphere in the interior and improve the orientation (Zafiris, 2010). At the same time these new solutions are energy efficient and also contribute to a positive energy consumption of vehicles **[Appendix 4].**

2.3 Principles of Process Management

2.3.1 Product Development Process Models

The product development process is a complex process with demanding requirements (Braess et al., 2013). A variety of different models are existing that can be applied to design a product development process. Models that find usage in the product development are for example the chain-linked model, the linear sequential model or the V-model.

One of the most common ones is the Stage-Gate-Model by Cooper. The intention of this model is to make the process and its management more effective and efficient by dividing it into Stages and Gates (Cooper and Edgett, 2006). Each stage is "…consisting of a set of prescribed, cross-functional, and parallel activities" according to Cooper and Edgett (Cooper and Edgett, 2006). Ahead of every stage is a gate which functions as a checkpoint. If a previously specified deliverable is not reached at the gate, the project can be stopped immediately at this point.

Typically the Stage-Gate-Model consists of five stages. However, depending on the process to be described, the number of stages can vary (Cooper and Edgett, 2006).

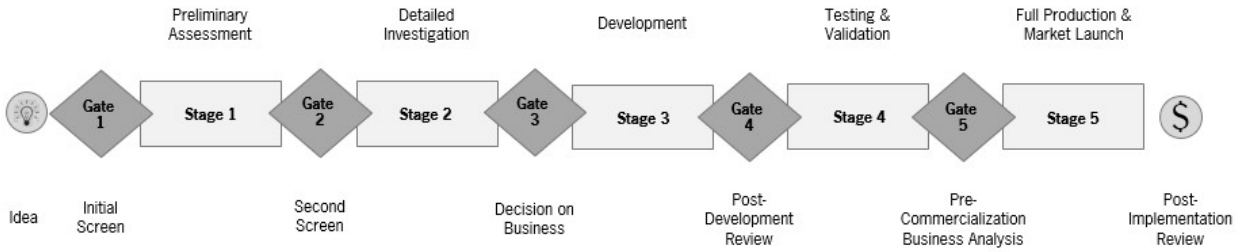

Figure 2: Stage-Gate-Process based on Cooper and Edgett

2.3.2 VDA Product Development Process

As there are a variety of different processes existing for the product development in the automotive industry, the VDA (German Association of the Automotive Industry) has analyzed the product development processes of various OEMs and is consequently giving a recommendation, on how the product development process in the German automobile industry should ideally be designed. The norm "VDA 4.3 – Qualitätsmanagement in der Automobilindustrie, Band 4 Teil 3: Projektplanung", published by the VDA in 1998 can be seen as a guideline. It contains the task fields as well as the milestones from the conception until the start of production. Thereby it needs to be adjusted by customers and suppliers (VDA, 1998, p.14).

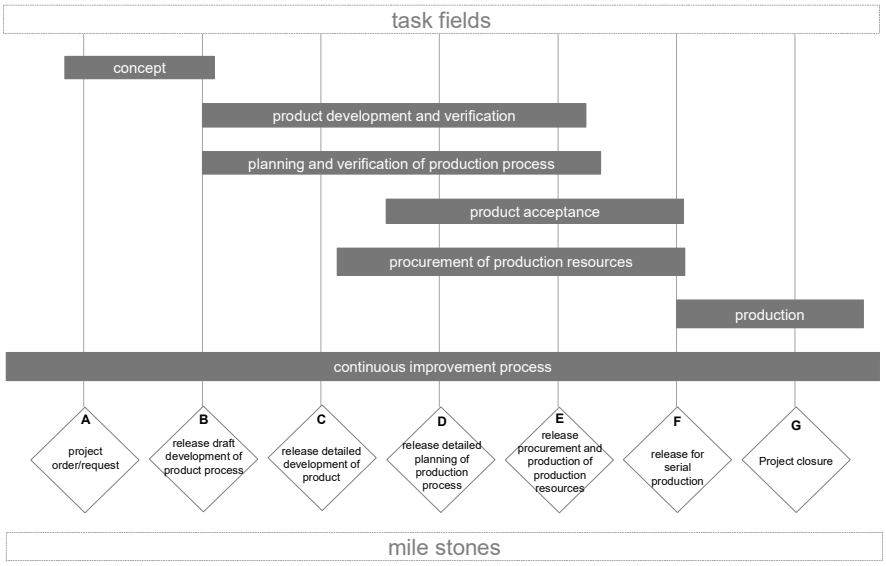

Figure 3: VDA Operating Plan (VDA, 1998, p.14)

2.3.3 Product Development Process at Porsche

After introducing the general product development process in the automotive industry by the VDA, in the next step the specific Porsche Product Development Process (PEP) will be introduced. It is the generic definition of the relevant processes of an ideal product development for vehicles at Porsche. The content of the PEP serves as the planning guide for Porsche vehicle projects. It is also in the style of the Stage-Gate Model and divided into 5 phases and 14 major mile stones and gates. In the following the 5 phases will be outlined and briefly explained. Due to confidentiality matters, particular milestones and quality gates cannot be detailed in this work project and specific dates be mentioned (Porsche e, 2015).

1. Product and Concept Definition: In this phase, innovation and pre-development topics will be transferred into a project, which will then be prepared for the start. A product profile will be available which contains information regarding the product features and competitive positioning. At the end of this phase, a target catalog as well as a technical product description will be available.

2. Concept Development: Based on the target catalog, the major functional groups will be tested and simulated through digital prototypes. In order to ensure the success of the product, also benchmarks with competitors will be undertaken. The phase ends with the passing of the specification book which is the benchmark for the series development in order to meet the customer requirements.

3. Series Development: The concepts developed in the concept phase will now be further developed to series production readiness.

4. Series Preparations: The series preparations phase is divided into pre-series. Main purpose of the series preparation phase is the running-in and stabilization of the production process.

5. Start of Series Production: The serial development starts with the SOP (start of production). Main content of this phase is to increase the number of produced vehicles per day within the production.

Figure 4: Product Development Process at Porsche (Porsche e, 2015)

2.3.4 Development Process of Semi-finished Materials

The development process of semi-finished products is one part of the Porsche Development Process. Within the PEP it focuses on the development of materials and colors for the vehicle interior. The process is divided into four sub-processes and one quality gate (Porsche d, 2016).

1. Creative Phase: In this phase, new design and color ideas will be developed independently from a certain vehicle project. Afterwards they will be presented to the executive board[3] to receive approval (quality gate).

2. Design Phase: After an approval has been received, the development of new colors starts. Firstly, a basic kit (interior coat, leather, combination plate) and the yarns will be developed. The reason why these materials are developed firstly, is the fact that they are the most reliable ones regarding the color retention and therefore the color data of these materials is easier to measure by a colorimeter.

3. Elaboration of Semi-finished Products: The color target is available in form of a decor coat plate or in exceptional cases through a real leather sample. The executive board decides about the assignment of colors and materials to a specific vehicle project. As soon as the color target is available, project specific semi-finished products such as carpets or foils can be developed and serve as a master sample for optic and haptic validation.

[3] Executive board consists of the CEO and the vice president of each main department (R&D, Procurement, Production and Logistics, Marketing and Sales, HR, Finance and IT)

4. Color Matching Process: The Color Matching Process is the last step of the semi-finished product development process. All samples/master samples are available and the planned SOP can be confirmed. Small adjustments of the semi-finished products can be made. (Porsche d, 2016)

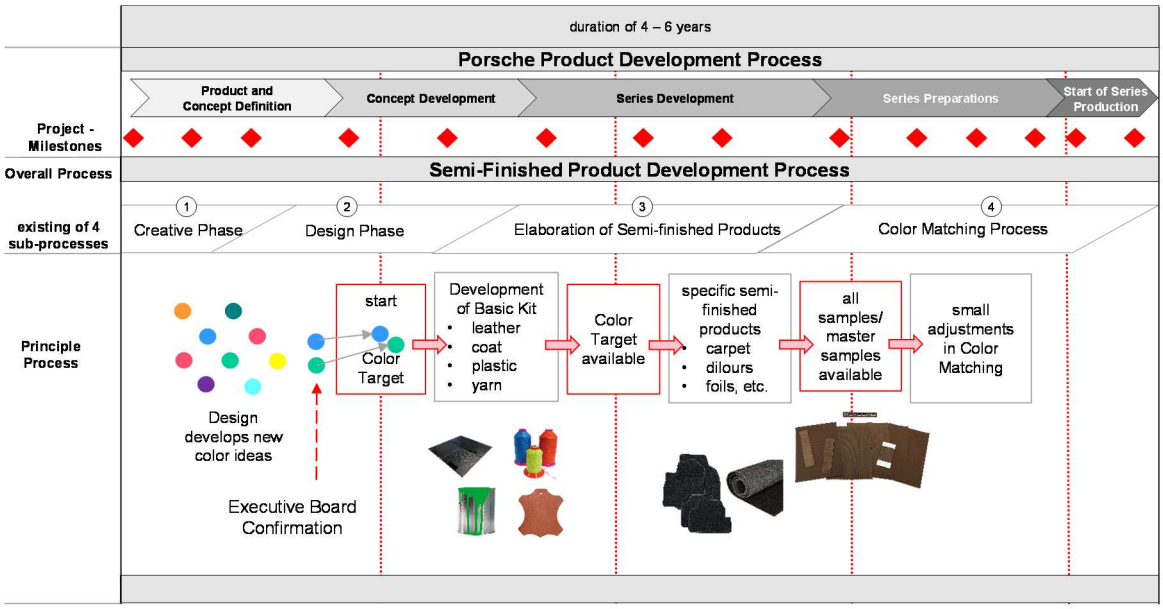

Figure 5: Development Process of Semi-finished Products (own figure based on Porsche data)

As figure 5 shows, the development process for semi-finished products starts with the creation of new color ideas in the creative phase. If these ideas are approved by the executive board, the color targets are going to be defined in the design phase before the master samples are produced and finally the color matching takes place. However, there is no pre-development phase in this process, which gives time for investigating the market and experimenting with new materials.

3 Research Gap

In the previous steps, the trend towards new and innovative materials in the vehicle interior has been outlined and the current development process of semi-finished products been described. The investigation of the interior development process has disclosed that the process only includes four main phases, which focus on materials that have been used at Porsche before. However, there is no phase specifically dedicated to new and innovative materials that have

never been applied by Porsche. If a new material is used by Porsche today, it is tested and proofed parallel to the regular development process. As a result, this often leads to delays due to the unavailability of a mandatory process to be followed and many times responsibilities are undefined.

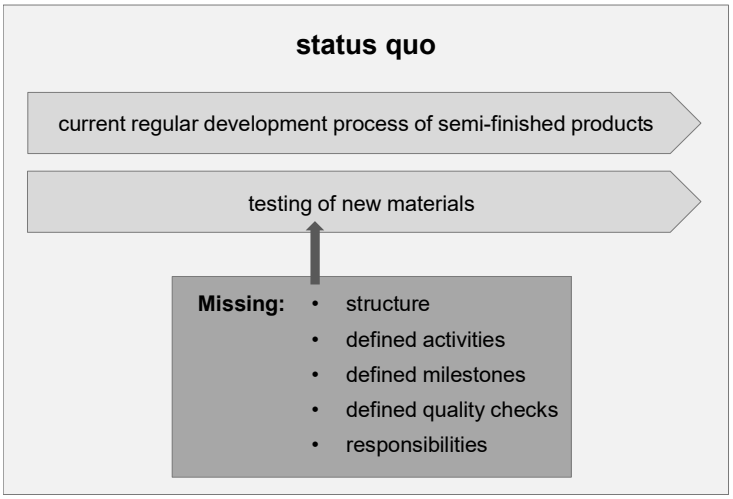

Figure 6: Status Quo (own figure)

Especially today, where development cycles continuously become shorter, it is of high importance to have dynamic and agile processes in the vehicle development (Kienbaum, 2016). In order to solve this challenge, the main goal of this work project is, to analyze innovations in the automobile interior field and to derive guidance on how to design the semi-finished product development process in order to include new and innovative materials in the future and ensure a smooth process and punctual start of production (SOP).

4 Concept and Implementation of a Process Framework

In the following, the previously explained theoretical basics will practically be applied. As a first step, the importance of the categorization and its structure will be outlined. Subsequently, the current development process of semi-finished products will be examined and a recommendation will be given on how Porsche should ideally include new and innovative

materials in its semi-finished product development process, in reference to the Stage-Gate model by Cooper.

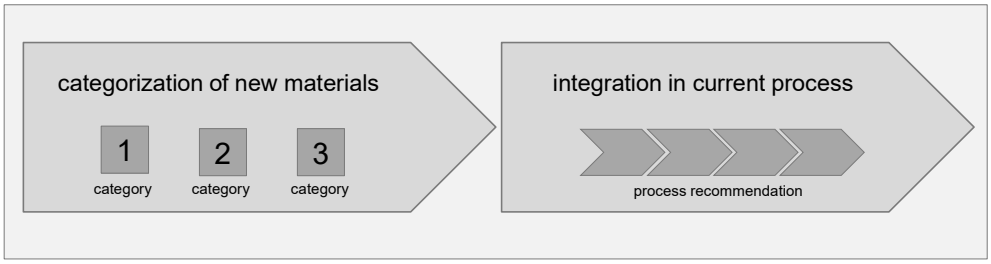

Figure 7: Concept (own figure)

4.1 Categorization of New Materials

Due to the fact that there are many different semi-finished products in an automobile interior such as textiles, leathers or plastics, it is difficult to come up with one process that fits for every kind of material. Some materials require more testing and have to fulfill more requirements in order to be released for automotive appliance while others need less. Therefore the idea is to categorize the innovative materials in main groups based on their current appliance and similar characteristics and features. Depending on which group the material belongs to, three processes will be developed in order to integrate new and innovative materials in the future.

The categorization is based on insights gained during the examination of expert interviews. To ensure the receipt of representative results, five experts from three different departments (design, material technology and material management) that are involved in the semi-finished product development process have been questioned. Based on their experiences and know-how from past projects, major categories have been created. The answers of the experts have shown that there are most similarities in the test scenarios and test durations of materials that have similar fields of application. Therefore three main categories based on the current field of application of the materials have been created. Due to confidentiality matters no quotes from the interviews can be directly used **[Appendix 5].**

4.1.1 Category 1 - Materials with Application within the Automotive Industry

The first group contains all innovative materials that have already been applied in the automotive industry however not at Porsche yet. An example from the past for this group of materials is the microfiber *Dinamica* which has been used in the seat middle of the Porsche GT3 RS in 2016 for the very first time **[Appendix 6].** It has an eco-sustainable production cycle and is 100% recyclable at the end of its life (Dinamica, 2016). *Dinamica* has been applied by other OEMs such as Mercedes-Benz (Mercedes-Benz, 2017) before. Due to the fact that the company *Dinamica* supplies other OEMs already, they are aware of the special requirements the material needs to fulfill when being applied in the automotive industry. This again was beneficial for Porsche since time for material testing could be saved. Porsche needed to undertake less material testing since the general automotive material feasibility has already been precisely tested by the supplier. Therefore an innovative material that has already been applied by another OEM before, does need some extra time for company specific testing and possible adjustments. However, this is less time consuming compared to a material that has never been applied in the automotive industry. Based on data from past experiences, it takes around 10-12 months to develop a material that has never been applied by Porsche but by other OEMs. Analog to the automotive industry one can find similar situations in the electronic industry. Contractors are supplying various OEMs and can therefore transfer their knowledge and experiences from one OEM to another. For example the US company *Qualcomm* supplies numerous OEMs such as *HTC* or *Asus* with processors for their smartphones (Qualcomm, 2017). Thereby they gain profound knowledge and become familiar with smartphone specific requirements which they can transfer to their future applications in the smartphone industry and save time and money.

4.1.2 Category 2 - Materials with Application outside the Automotive Industry

The second group includes all materials that are new and innovative and have never been applied in the automotive industry before, however in other industries. Very often these materials have their origin in the fashion or furniture industry or come from architecture. Suppliers from these industries are already experienced with the materials and have empirical values, however not in the automotive industry. Therefore as a first step the material feasibility needs to be tested, to check if it is generally qualified for automotive usage. In further steps the material needs to go through specific material testing in order to test if it withstands the strains in an automobile. Based on previous experiences at Porsche, it takes around 22-24 additional months, to develop a material that has never been applied in the automotive industry. An example from the past is *woven leather*. It has already been applied in the fashion industry and became well known e.g. through the Italian designer Bottega Veneta who used this kind of leather style for the production of his handbags (Veneta, 2016). However, to make the material able to be applied in the automotive industry, Porsche had to go into research and was looking for a suitable lamination to make the material resist wear. In the aerospace the necessary technology was found, to make the material strong and with a resistant surface that has an extremely high burning rate. In 2009 the *woven leather* has been applied for the first time in the Porsche special edition model 911 Sports Classic (Harley, 2010). Due to the fact that it has never been applied in the automotive industry before, various inspections were necessary beforehand. In the automobile production, materials are subject to completely different types of abrasions than in fashion. Therefore the second category of materials that have only been used in industries outside the automotive industry has been created **[Appendix 7].**

4.1.3 Category 3 – Materials that have never been applied

The third group includes materials that are completely new and innovative. These materials have neither been applied in the automotive industry nor outside of it. They are newly developed

and until now there are no empirical values and no testing has been carried out. For this reason, it may take more time to test and develop these materials. Especially to test the general automotive suitability of these materials may take much longer than for materials that have already been applied in the industry. Therefore a specific duration for this development process cannot be determined. These materials may have unexpected characteristics and thus take an undefined amount of time to be developed. Also there are no best practices at Porsche from the past. So far there has never been a material at Porsche that hasn't been applied before. However, one still need to consider this third category since this case may still occur in the future **[Appendix 8].**

Figure 8: Additional Time per Category (own figure)

4.2 Process Framework

The examination of the current semi-finished product development process has disclosed that in order to integrate new and innovative materials successfully, a pre-development phase is necessary. Currently, the respective departments are dealing with innovative materials parallel to the existing development process of semi-finished products. However, deadlines and responsibilities are not defined. New materials are developed but there are no defined gates where the general feasibility of the material is checked. In the past, this led to situations where materials and their respective colors have been developed for several months or even years and only shortly before the start of the series production it was realized that the material doesn't fulfill all the required characteristics. Consequently this also led to financial losses since a serious amount of money has been spent for the development.

The expert interviews have crystalized out that it is essential to already take care of new innovations in advance of the regular development process. Before the start of the color developing with suppliers, it needs to be found out if a material is feasible at all. Therefore a pre-development process with several quality gates has been designed. Depending on the category the materials are allocated to, this pre-development process differs. Three pre-development processes respective to the before introduced three categories have been designed, using the Stage-Gate model by cooper with various stages and quality gates **[Appendix 9].**

4.3 Embedding of new Processes

4.3.1 Process for Category 1 Materials

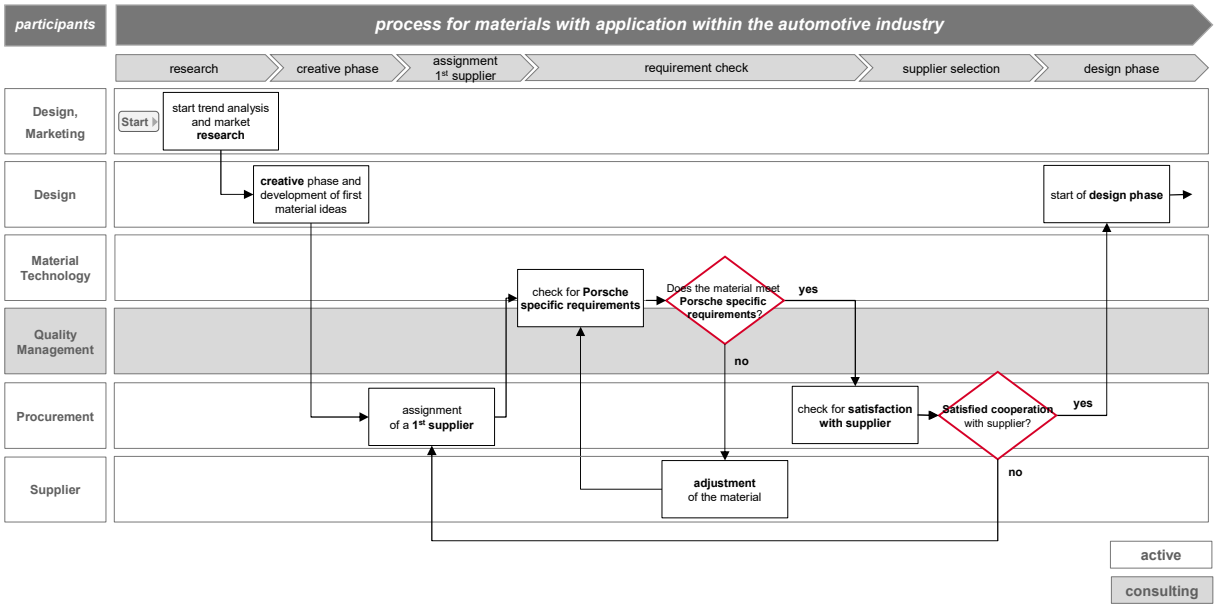

Figure 9: Category 1 – Materials with Application within the Automotive Industry (own figure)

Category 1 contains innovative materials that have already been applied by other OEMs.

The first activity of this process is the *research* and look out for new trends and market demands. Thereby the marketing department will be responsible for the market research. This task includes the investigation of which materials and products are currently on the market and in particular what competitors are doing. Furthermore information needs to be gathered on what the recent customer demands and purchasing criteria are and the design department will look for new trends.

The following activity is the *creative phase*. The design department is consolidating the ideas from the research and starts creating the first material ideas and drafts for future vehicles. The whole development of these ideas however is independent from specific vehicle projects. This will only be done after the colors have been developed at a later point in the process.

As soon as the initial ideas are created and determined, a *first supplier will be assigned,* to deliver a sample, based on the specifications developed during the creative phase. Criteria regarding the selection of the supplier include price, quality, duration, previous experiences and reliability. For this task the procurement department will be responsible. However, they are in constant coordination with the material technology and quality management departments. In this part of the process, it is not necessary to have a quality gate for each activity yet. The quality and status of these three activities will be checked with the next gate.

In the following activity the material technology department will check if the delivered material fulfills the *Porsche specific requirement criteria* **[Appendix 11].** This is done with support of the quality management department as a consulting party. A general automotive suitability does not need to be tested here, since the material has already been applied by other OEMs. However, the material may not meet all Porsche specific requirements. Therefore the status of the material is checked by the quality gate following the activity. In case the material doesn't meet the requirements, it needs to be adjusted and go through a loop. The adjustment needs to be done by the supplier, however Porsche is in close contact with the supplier and gives recommendations on how to improve the material in order to ensure it will meet Porsche specific requirements. Thereafter it goes into the activity of checking the requirements again and follows the process. Based on experiences from past projects, usually not more than four loops of adjustments are necessary in order to meet Porsche specific requirements.

If all requirements are met, the procurement department will check in consultation with the material technology and quality management department in the next activity, if the *cooperation*

with the supplier is satisfying. This activity again is followed by a quality gate. If all criteria **[Appendix 12]** are met, the design phase can start. Even though the material fulfills all Porsche specific requirements, it may still happen that the cooperation is not satisfying for example when the supplier doesn't deliver on time or in stable quality. In this case, another 1st supplier can be assigned and the fulfillment of Porsche specific requirements need to be tested once again with the new supplier.

As soon as the supplier is set, the *design phase* can start and the development process of semi-finished products as described in the theoretical framework continues (see 2.3.4).

4.3.2 Process for Category 2 Materials

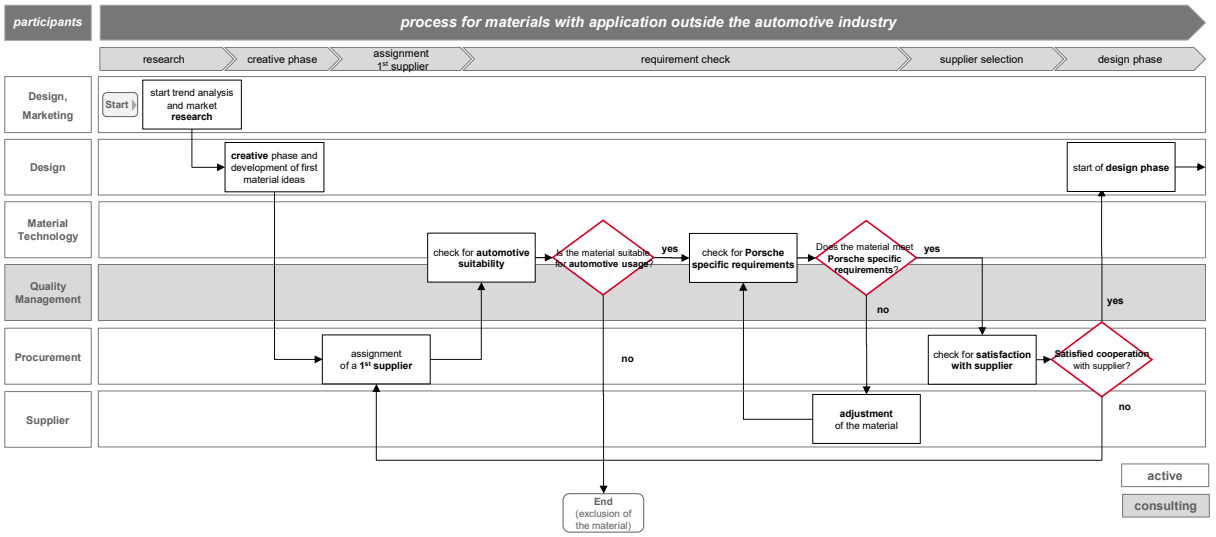

Figure 10: Category 2 – Materials with Application outside the Automotive Industry (own figure)

The pre-development process of Category 2 materials starts analog to Category 1 with the *research* and trend analysis activity, where information about current customer demands and purchasing criteria need to be gathered by the marketing department. At the same time the design department is responsible to look out for new trends. Specific design fairs should be visited but also fairs for innovations in the field of fashion, architecture or furniture, in order to derive possible trends for the automotive industry. After these information are transferred into first material ideas and drafts in the *creative phase*, the *first supplier will be assigned* to deliver a prototype of the material. Equal to the process of Category 1, no gates are required here.

As soon as the first supplier has been assigned, the material technology department with support of the quality management department will check the general *automotive suitability* of the material. Other than in Category 1, these materials have never been applied in an automobile before. Therefore it might happen, that the material isn't *suitable for automotive usage* at all. In case it doesn't fulfill the required characteristics that are necessary **[Appendix 10]**, it will be directly excluded in the quality gate which follows the activity. This doesn't mean that the material can't be used in an automobile at all. However, at the current point it doesn't meet the required specifications and must therefore be adjusted. It may be suitable for automotive usage at a later point after several adjustments have been made, however in this case the process would start from the beginning again, since also the design department would need to go into research again and make major adjustments to their drafts and ideas.

If the requirements are fulfilled, in the next activity it will be checked whether the material also fulfills *Porsche specific requirements*. If not all criteria are fulfilled at the following quality gate, the material needs to be adjusted and goes into a loop analog as in Category 1.

If the material meets all Porsche specific requirements, the procurement department will audit the *supplier satisfaction* in the subsequent activity. This activity is also followed by a gate. If not all criteria are met regarding the supplier satisfaction, a new supplier will be assigned and the new material needs to be tested again. If the cooperation with the supplier is satisfying, the *design phase* can start.

Since in Category 2 testing for general automotive feasibility needs to be undertaken and several loops in the adjustment to Porsche specific requirements may be needed, more time has to be considered than in Category 1. In past projects the adjustments took up to 20 months. Therefore one can consider a total time of around 22 to 24 months for the pre-development phase of Category 2 materials.

4.3.3 Process for Category 3 Materials

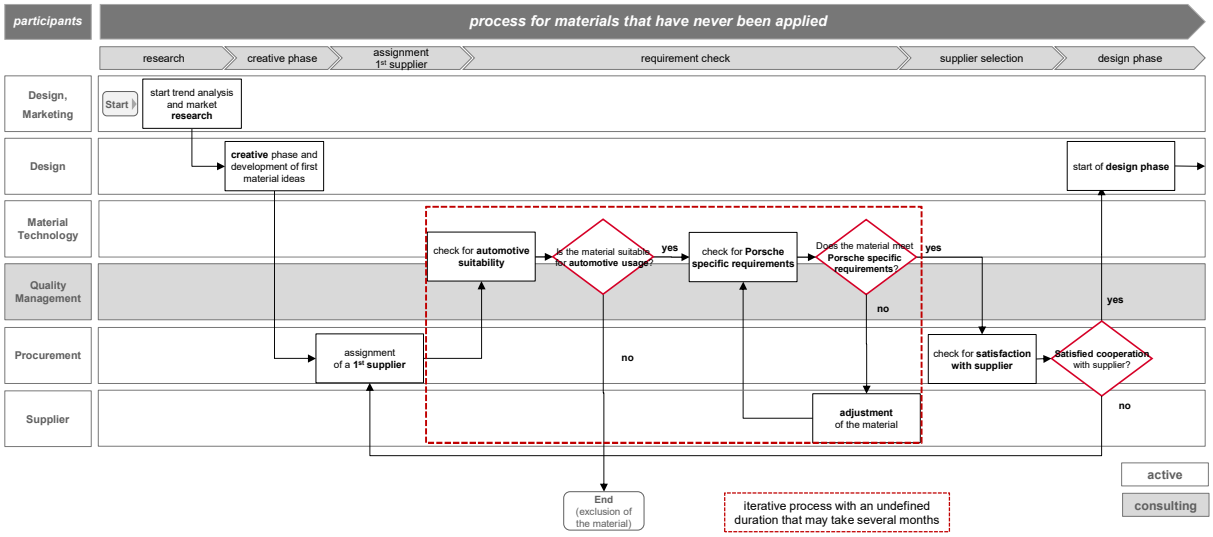

Figure 11: Category 3 – Materials that have never been applied (own figure)

Analog to the process of Category 2, also the process for Category 3 starts with the research, followed by the creative phase and the assignment of a first supplier. As described in the previous process, the *general automotive suitability* of the material and the *fulfillment of Porsche specific requirements* need to be checked. If the material doesn't fulfill the requirements for automotive usage in the first quality gate, it will be excluded. Otherwise the fulfillment of the Porsche specific requirements will be checked in the next activity and its subsequent quality gate.

In this third group of completely new and innovative materials, the testing of automotive suitability and adjustments to Porsche specific requirements may take an undefined amount of time, since the material has never been applied before. Therefore no data is available that provides information about the duration of the process. It may take several months or even years to make the material finally applicable in a Porsche vehicle.

If the material fulfills all requirements, the process continues analog to the previously described processes of the Categories 1 and 2. If the cooperation with the supplier is successful, the *design phase* can start. Otherwise a new supplier will be assigned and the material will need to be tested again.

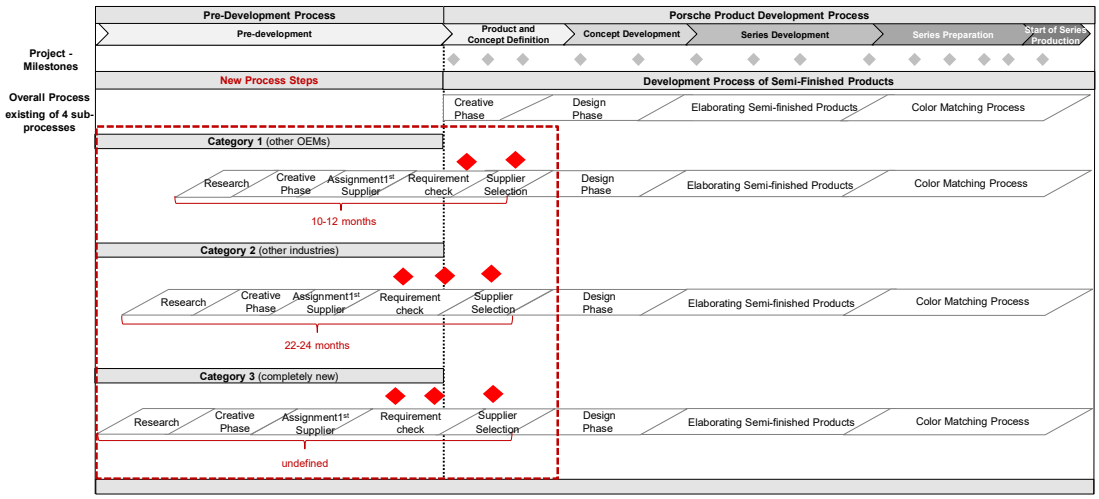

Figure 12: New Development Process for Semi-Finished Products (own figure)

To sum it up, figure 12 summarizes the three different pre-development processes related to the previously introduced categories. It outlines that materials that have already been applied by other OEMs need less pre-development time than materials that come from other industries such as from fashion or architecture. While materials that have been applied by other OEMs need around 10-12 months of pre-development time, materials from other industries need on average around 22-24 months for the testing of their general automotive usability and the fulfillment of Porsche specific requirements. Innovative materials that have never been applied yet, have an undefined pre-development time. It is an iterative process with an undefined duration that might take several months or even years.

5 Conclusion and Outlook

5.1 Conclusion

This work project has demonstrated that new and innovative materials cannot easily be integrated in the current development process of semi-finished products at Porsche. Every material has its own and varying characteristics and features and needs to be integrated differently. However, to make the whole process design less complex, main categories have to be created to allocate the semi-finished products to. Different from the current development process, it is important to discover and develop new and innovative materials not solely parallel

to the current process, but actually create an own pre-development phase. Based on their previous field of application, one can derive their rough characteristics and development time. The analysis has disposed that materials that are innovative but have already been applied by other OEMs are less time consuming. Materials that have been applied only outside the automotive industry need more development time and for materials that are completely new and have never been applied yet, one cannot determine a certain duration however one can anticipate a longer duration. Since these materials are new, there are no experiences available and the material may go through several loops during the development process.

To sum it up, the analysis of the current process has shown that new and innovative materials cannot be integrated in the current process easily and rapidly. Instead, one need to establish a pre-development phase to know about the general feasibility. And this pre-development phase is again dependent on the respective category the material belongs to.

5.2 Outlook

This project has been an important step for Porsche and the Color Matching Department. Especially for the new Porsche Mission E flagship project, where a large amount of new and innovative materials will be applied, this process is of great significance. The work project serves therefore as a guideline on how new materials should preferably be categorized and included in the current process of semi-finished materials, in order to ensure a smooth process and on time start of production. After having presented the results of this work project to the responsible persons in the respective departments of design, marketing, material technology, quality management and purchasing, the next step will be the implementation and rollout of these pre-development processes. This however may take some time. A detailed planning phase will be of high significance in order to efficiently allocate resources such as manpower, time and money to the project. This is planned to be started at the beginning of the fiscal year 2017.

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