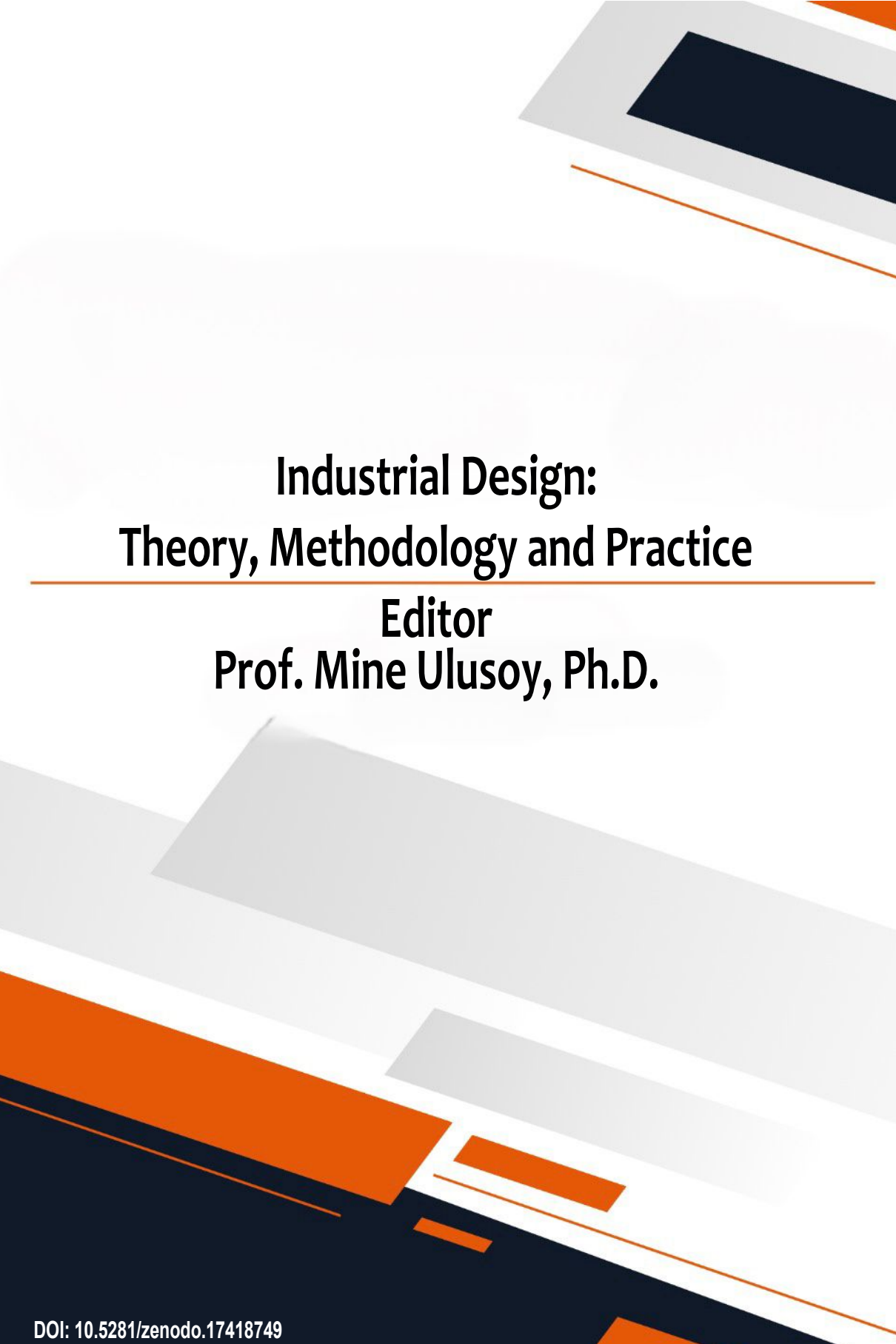




Industrial Design: Theory, Methodology and Practice

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Industrial Design: Theory, Methodology and Application

Editor

Prof. Mine Ulusoy, Ph.D.

Publisher

Platanus Publishing®

Editor in Chief

Prof. Mine Ulusoy, Ph.D.

Cover & Interior Design

Platanus Publishing®

The First Edition

October, 2025

ISBN

978-625-7078-18-4

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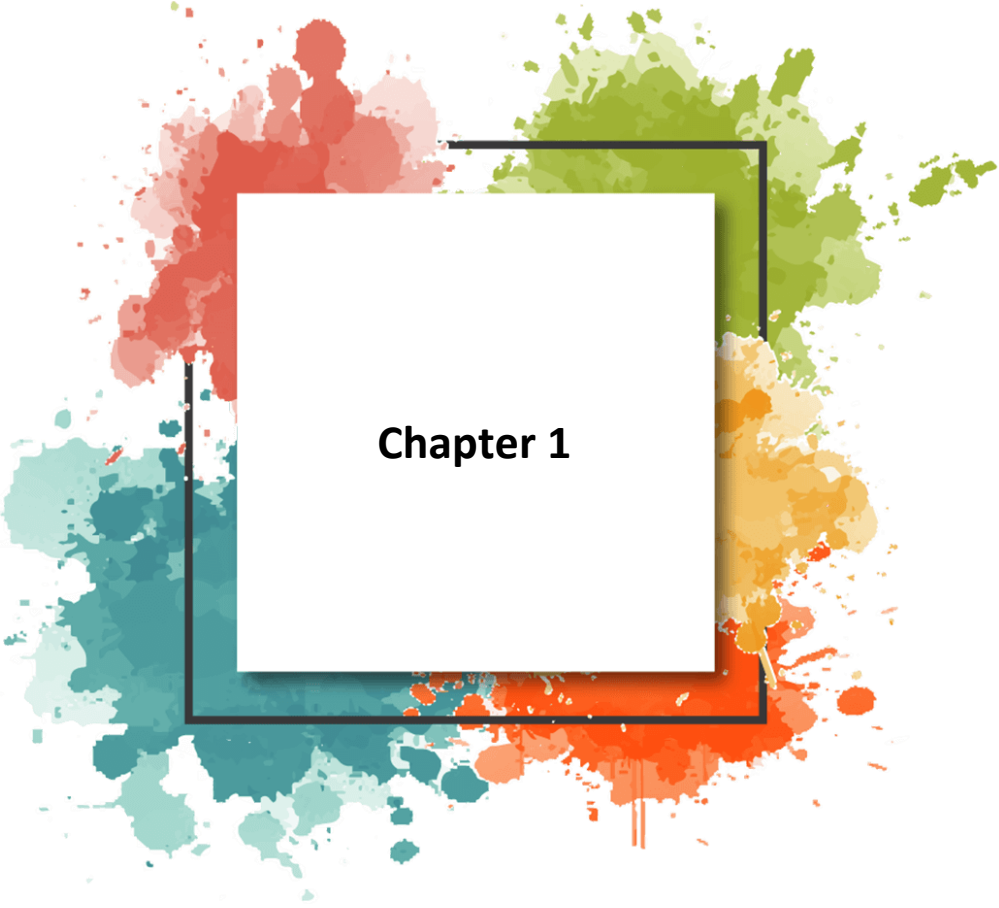
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Chapter 1

The Comparative Analysis of Automotive Design Processes and Concepts Created by the Industrial Design Discipline

Fuat Ali Parker¹

The primary aim of the research is to comparatively examine how the stages of automotive design within the industrial design discipline are utilized and which fundamental concepts show significant development under competition. Therefore, the case study method was chosen for this research. The field research of the study was conducted through face-to-face interviews with ten experts from six automotive main industry and ten automotive sub-industry companies. The results of the field study conducted under this record reveal important variables for the development of the profession within the industrial design discipline of automotive design. Additionally, the fact that automotive industry products generate high income for national economies under global competition and the establishment and development of the relevant industry at the national or international level, or the identification and fulfillment of its needs, make such research important. However, there are significant differences in information input between redesigning an existing vehicle and designing a new vehicle from scratch. Although these differences are solution-oriented, ranging from after-sales problems to supply part problems or assembly part problems, they also determine different method preferences for customer or user experience measurement results. At the same time, the study also reveals research topics and subjects at the micro level.

Keywords: industrial design discipline, automotive design, industrial design processes, and new product development processes.

Introduction

Sub-specializations of contemporary automotive design activities; stage definitions and core tasks in the product development process, and areas of expertise related to current design in the new product development process constitute subsets of the proposed research area.

The design stages and terminology for the automotive industry products listed below, along with the concepts in the flow steps, were developed based on field

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research and literature review. Vehicle Architecture (VA): This is the specialized field that defines and plans the conceptual design structure of a newly designed vehicle, its place within the product family, vehicle class, main and intermediate modules, versions, and similar values (Figure 1). As shown in Figure 1, it defines the structural dimensions of the newly developed vehicle, its position in the product range in proportion to the product portfolio, and the common infrastructure platform or parts with the products on the existing production line (Figure 1). The VA approach plays a role in determining project objectives or design acceptance criteria that precede automotive design activities in the product development process (Figure 1).

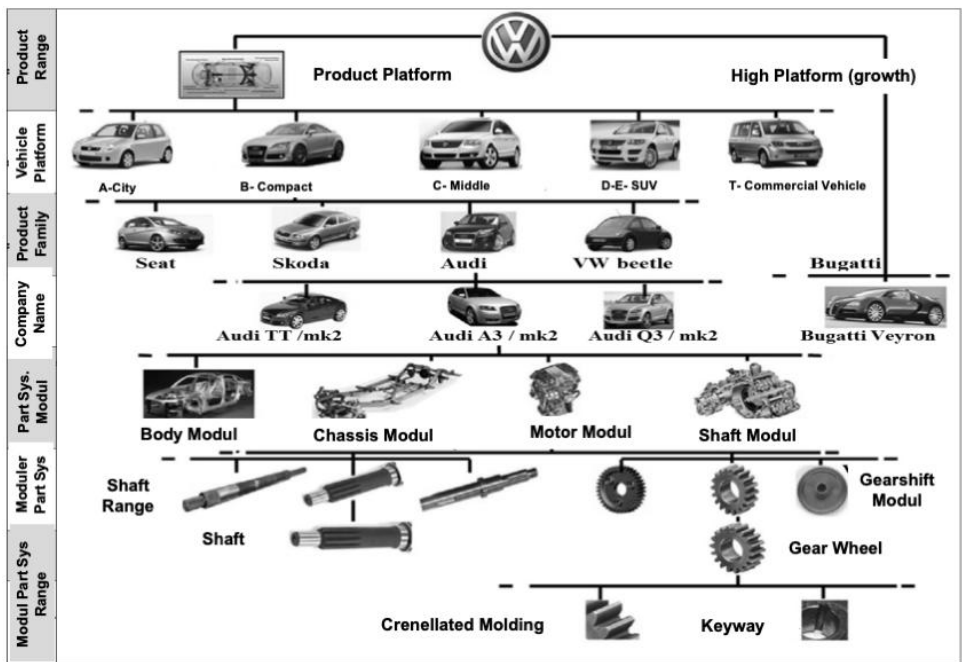


Figure 1. Vehicle architecture and product platform phase (Tovey, 2012).

As shown in Figure 1 above, global automotive manufacturers, reveal their different brand applications, common parts usage and cost reduction approaches, with the same or complementary parts. In Figure 1, an example of a different brand application, updated with the use of common parts, is given under the assembly performed in the same factory (Tovey, 2012). Vehicle Package (VP): The concept of vehicle packaging, which constitutes the core area of expertise and its main phase, determines the vehicle's load-carrying capacity, weight, or usable area, along with interior and exterior cargo storage, storage features, various usage areas, transportation ergonomics, and similar approaches (Figure 2). As illustrated in Figure 2, access to the vehicle's trunk or engine compartment,

as well as user storage areas within the interior, encompass approaches related to the development of both ergonomic and functional criteria. Transportation and modeling of storage and storage areas in automotive design activities fall within the scope of VE engineering (dynamic weight calculations) along with VP expertise (Figure 2).

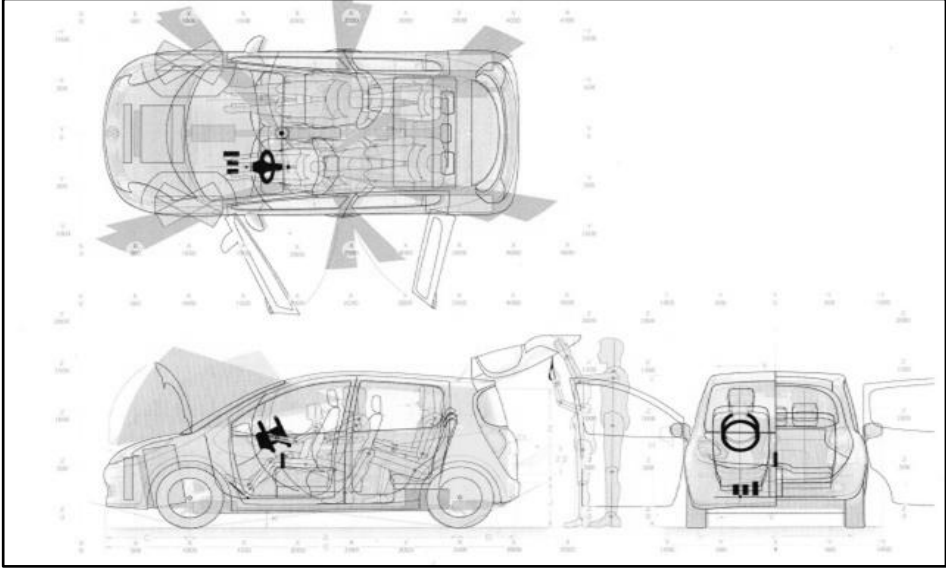


Figure 2. Vehicle packaging area structure (Weber, 2009).

Powertrain Design (PTA): This is the field of study where the design or calculations are carried out regarding the location of the vehicle's driveline and related components, including the engine (Figure 2). As shown in Figure 2, the need for warm or cool air generated by the engine and chassis components is met by vents created in the vehicle's exterior enclosure panels. When looking at the overall vehicle structure, the vehicle body meets the airflow needs of the engine chassis (Figure 3). In other words, it is the main element that affects the main body and automotive design (Figure 3).

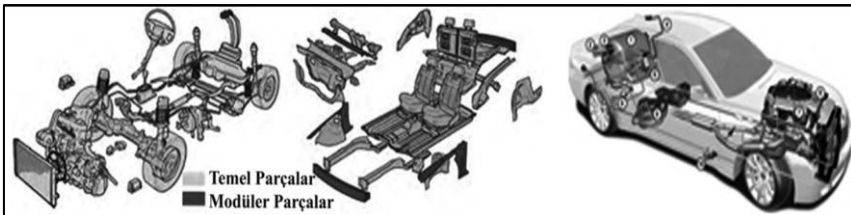


Figure 3. The motor chassis development stage of the vehicle (Weber, 2009; Parker, 2018).

The vehicle's motorized chassis or powered drivetrain, which also incorporates structural safety elements such as acceleration and braking, is defined at this stage (Figure 3). At the entry level of automotive design, it forms platforms where vehicle dimensions are transferred, minor changes are made through lengthy testing and analysis, and different models or classes of vehicles are shared (Figure 3). Cost Accounting (CA): This field of expertise, which conducts pre-design work on automotive design, ensures the formation and control of new product development projects, including the entirety of the new parts or main vehicle, as well as the production investment, resource usage (project, materials, labor, etc.), and similar economic values of the new product development and design project or new vehicle (Figure 4). Cost verification expertise, which focuses on the new product development process and establishes, directs, or controls costs, establishes a balance between the targeted values of the new vehicle project. As shown in Figure 4, the material weights of the parts of the new vehicle design, as well as production investments, are carried out under cost verification studies.

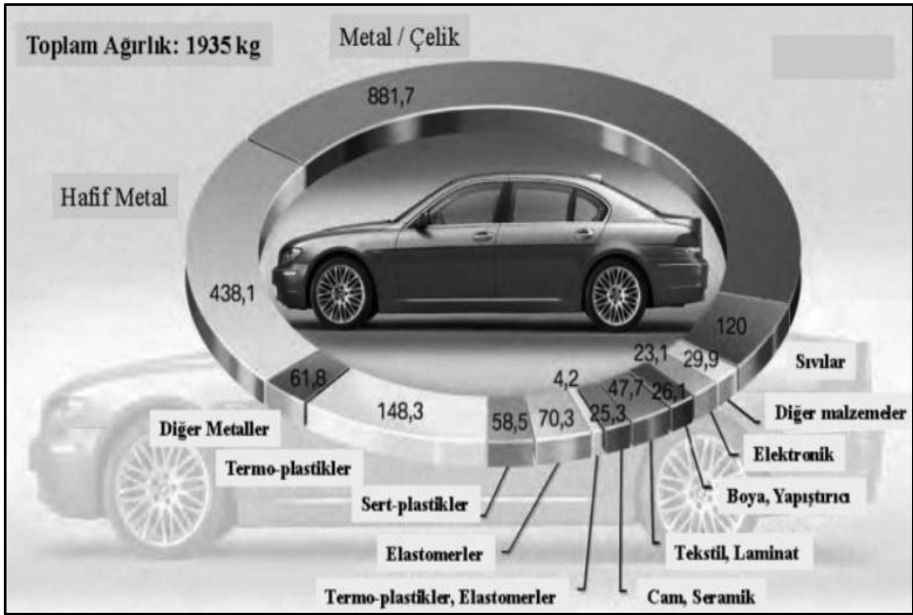


Figure 4. Weight distribution of materials on the vehicle (Weber, 2009).

As illustrated in Figure 4, within the automotive design phases, material strength and usage, along with form and function, determine both the homogeneous weight distribution and balance on the vehicle, as well as fuel consumption, range, and similar values. Furthermore, the design of each component of a vehicle reveals material and investment alternatives during the

mass production, assembly, and procurement phases, as well as during cost studies (Figure 4). Doodle Design (DD): This is the first design phase in which the new vehicle project's intended innovations and usage scenarios are created using sketches, and the areas where new functions affect the vehicle's exterior are identified (Figure 5). As depicted in Figure 5, innovations in new vehicle project objectives and market research results ultimately create interaction within the vehicle's exterior. This interaction fosters a flow throughout the product development process, including design studies, sketches, and usage scenarios (Figure 5).

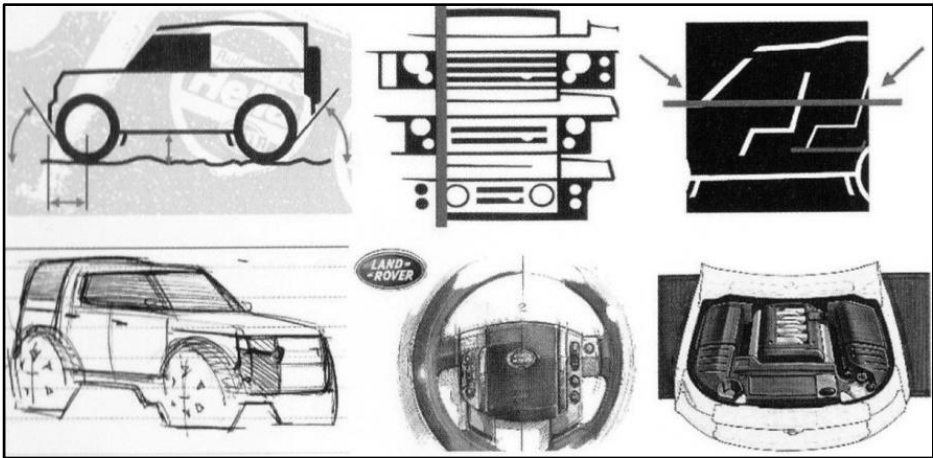


Figure 5. Preliminary idea draft sketch (doodle) stage (Tovey, 2012; Paker, 2018).

The DD phase, which directs the form or usage structure of new technologies on new vehicles, is the beginning of the automotive design phase, which begins in a 2D paper environment (Figure 5). As shown in Figure 5, automotive design preliminary ideas and drafts are expected to reflect similar characteristics to the existing product family, or to reflect core values that are a continuation of the existing product family. Exterior Trim Design (ET): This step constitutes the automotive design flow, primarily involving the design of the supporting main body structure (Body in White (BIW)) and the functional exterior coverings of the connected parts (Figure 6). Scale (1/8, 1/5, 1/1) clay models: exterior mock-ups, virtual prototypes, rapid prototypes, virtual renderings, real-time renderings, virtual assembly, Class-A surfaces, testing, structural analyses, and similar automotive design activities encompass the work of this stage (Figure 6). It encompasses all work steps, including the details of the parts and connections located outside the vehicle, which form all exterior surfaces and are accessible to the user or service technician (Figure 6). As depicted in Figure 6, the entire process, from the assembly phase of the production line to the reinforcement of

the safety cage that forms the main structure, is carried out in the same flow, with many variables. The final vehicle is verified by crash and rollover tests (Figure 6).

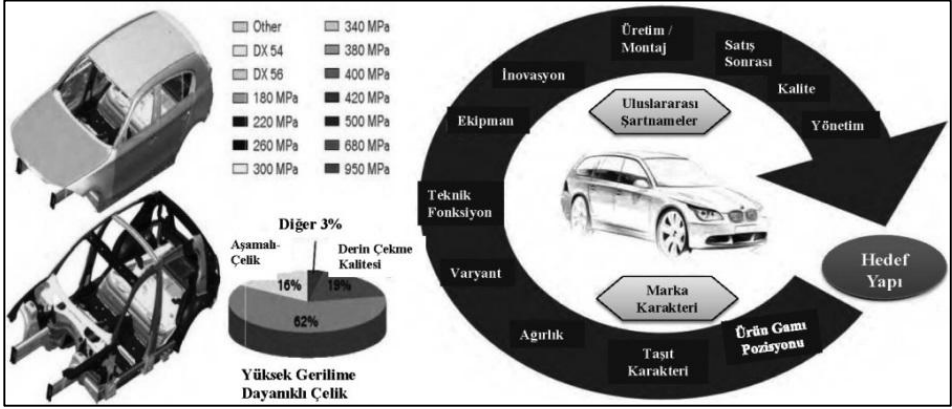


Figure 6. Verification phase of exterior trim parts (Weber, 2009).

As illustrated in Figure 6, exterior trim design encompasses the structural values driven by the vehicle's functional interior ergonomics and the engine chassis. Therefore, the role of exterior trim parts within the automotive design phase comes into play after the initial values are established (Figure 6). Interior Trim Design (IT): This design encompasses the design of the components or connections within the vehicle that interface with the user and product living spaces (Figure 7). As shown in Figure 7, the design of these parts that interface with the user involves many interdisciplinary variables and approaches, from safety to comfort.

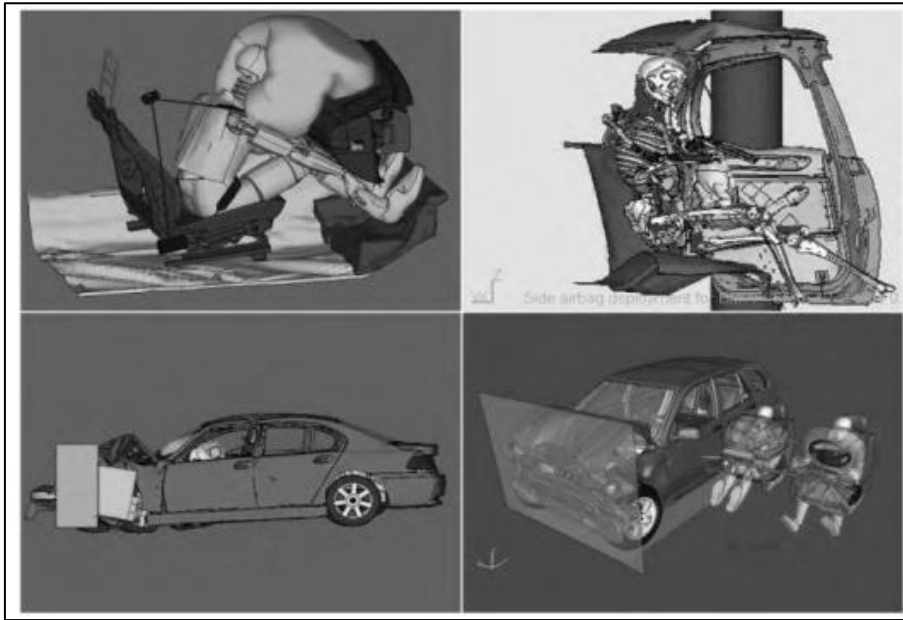


Figure 7. Interior trim part verification phase (Weber, 2009).

The interior trim validation phase establishes the interior layout of automotive design variables, designed with new technologies (Figure 7). Interior trim design also defines the alternative structures implemented alongside user experience activities in automotive design (Figure 7). 2D Styling: This is the structural sketching phase, where conceptual ideas are created in a two-dimensional paper environment, and the basic character lines of the new vehicle's exterior are finalized (Figure 8). This is the final design phase, with presentations and approvals, before 3D CAD models are developed for the new vehicle. As shown in Figure 8, it is the automotive design phase that allows the discussion of product development expertise and structural innovations in automotive design activities on paper.



Figure 8. 2D Sketch design phase (Tovey, 2012).

The 2D sketch phase, which constitutes the initial step of the automotive design phase, continues with independent trial studies after the vehicle class and targeted vehicle dimensions, or project goals, are determined (Figure 8). However, as shown in Figure 8, core conceptual values that demonstrate the character change or continuity of the product family guide the designs (Figure 8).

3D Media Presentation (3MP): This involves presentations that are presented in a two-dimensional paper environment, where the selection and approval phases of vehicle design alternatives arising from the automotive design phase take place, or in a computer environment, using three-dimensional models and animated animations (Figure 9). As shown in Figure 9, various methods are used in this design phase, where the project is reviewed or management (company, project) selects new vehicle alternatives.

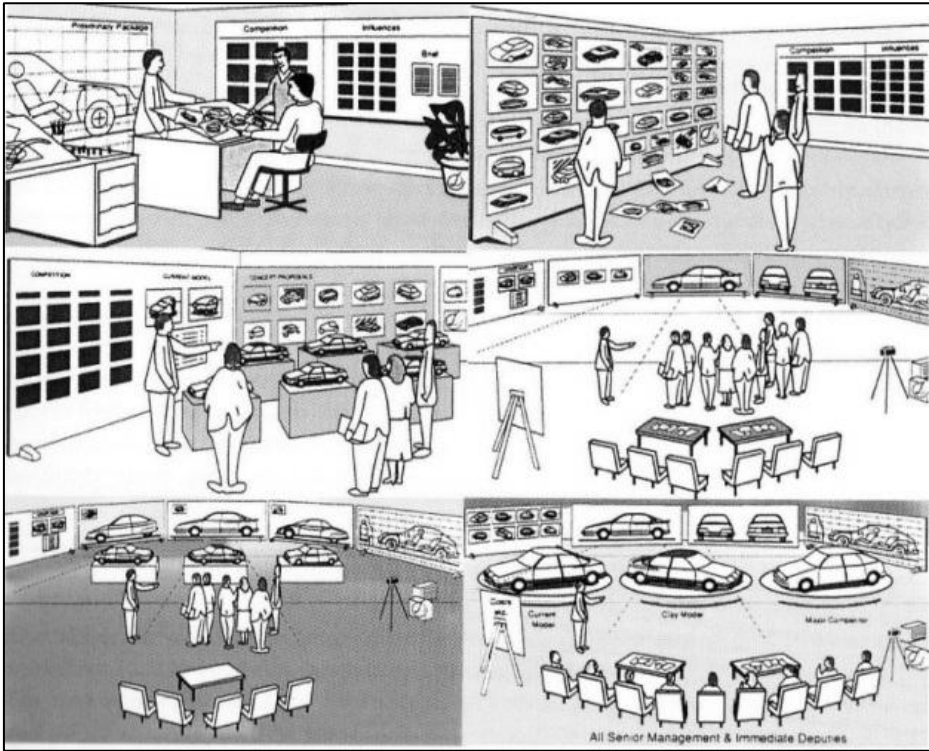


Figure 9. media presentation and approval phase (Tovey, 2012).

The 3D media presentation and approval phase exhibits an iterative structure, where the results from the automotive design phases are evaluated and the targeted vehicle concepts are incorporated into the design through adjustments (Figure 9). Therefore, the media presentation phase provides a collaborative environment where interdisciplinary variables that ensure continuity throughout the automotive design phases until the vehicle receives design approval are discussed (Figure 9). Clay Model Design (CM): In the automotive design field, this is the 3D creation of alternative new vehicle models at scales of 1/8, 1/5, and 1/1 using special clay mud, which can be shaped by heating in special ovens at 80°C and has a stable form structure at room temperature (Figure 10). As illustrated in Figure 10, this application is used to observe the volumetric effect of the new vehicle's exterior shell form. Initially, it is implemented manually using sketches and later with a CNC machine. This is the iterative design phase of new vehicle exterior modifications using a 3D CAD model and CNC (Figure 10).

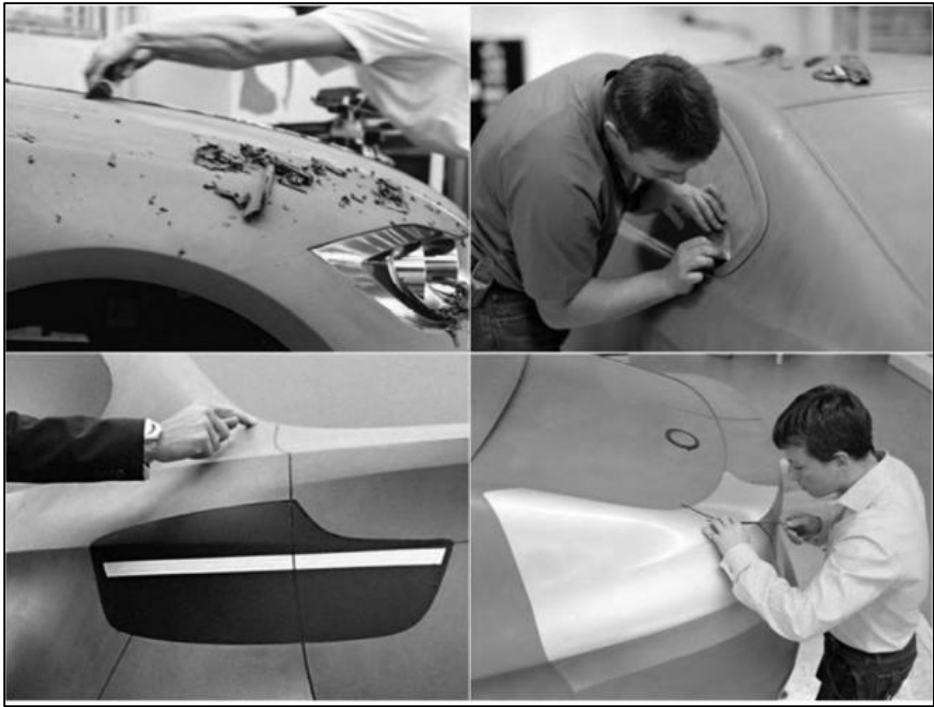


Figure 10. Clay (mud) model design phase (Weber, 2009).

As illustrated in Figure 10, the clay modeling step, the first interdisciplinary step in the automotive design process, is the process where 2D sketches come to life in 3D. Furthermore, the clay modeling phase begins with manual work and continues with 3D digital scanning in a computer environment (Figure 10). Digital scanning & CNC modeling (CD): This is the step involved in surface development or modifications of alternative clay models created during the automotive design phase: digitizing physical part assemblies using a point cloud and iteratively processing the digital data with the physical model using a CNC device (Figure 11). As illustrated in Figure 11, this is the machine-milling-assisted design phase, which includes compatibility studies of the clay model and rapid prototype parts.



Figure 11. Digital clay scanning & CNC clay modeling phase (Tovey, 2012).

This stage, where vehicle designs created in the 3D clay model phase are transferred to a digital computer environment, entails costly and time-consuming modifications requiring investments in a three-axis milling machine to exact vehicle dimensions (Figure 11). As depicted in Figure 11, the automotive design phase, which follows the iterative timeline of 3D scan data editing in a computer environment, exhibits an interdisciplinary support structure and requirements. Vehicle ergonomics and user design (Vehicle Environment and Ergonomics (VEE)): This is the interdisciplinary automotive design phase, focusing on user ergonomics, including analyses of internal reflections from the driver's viewpoint or the vehicle's exterior windows located within the viewpoint (Figure 12). In addition, as some of them are shown in Figure 12, it includes ergonomic studies consisting of the use of static and dynamic parts such as getting in and out of the vehicle, opening and closing the trunk, opening and closing the fuel tank, opening and closing the engine cover, gear shifts, driver-steering wheel, driver-display, driver-mirror and so on.

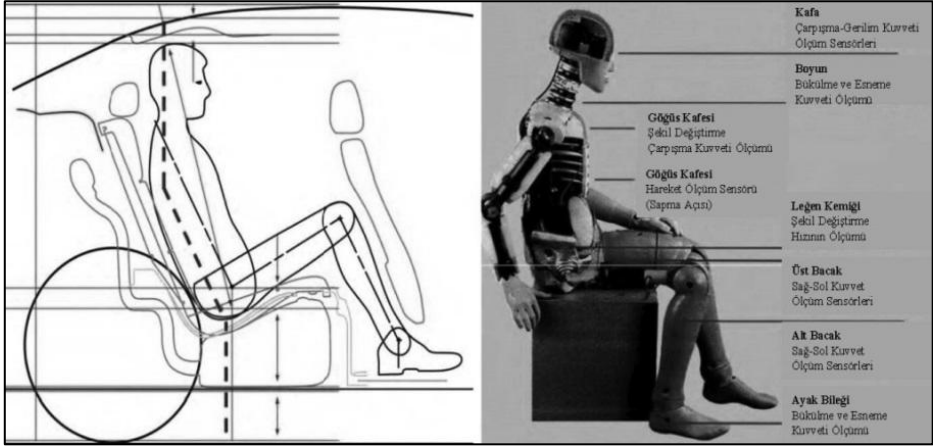


Figure 12. Ergonomic design phase of the vehicle (Weber, 2009).

The ergonomics of the vehicle and driver, or passenger and cargo, are decisive variables in automotive design (Figure 12). Furthermore, the automotive design phase, which experimentally analyzes the parameters that determine driver vehicle use and safety, also works for structures within the tolerance range of different human anatomy (Figure 12). Interface Design (ID: Interface Design): The primary communication between the vehicle and the driver is provided by the displays on the dashboard (Figure 13). As illustrated in Figure 13, the design of vehicle displays and warning systems constitutes the field of interface expertise. The analysis, planning, and design of all displays or controls that form the vehicle's user interface occur at this stage. Interface control, conducted through real-time analysis in a virtual environment, is included in the later stages of the automotive design flow (Figure 13).



Figure 13. Vehicle interface design phase (Weber, 2009).

In vehicle interface design, the ergonomic positioning of the instrument panel, along with the vehicle's dynamic use and the orientation of referents, place the field of study among the interdisciplinary automotive design stages (Figure 13). Furthermore, as shown in Figure 13, the driver's ergonomics, including the areas of use and their functional location or access to function keys, as well as their priority and frequency of use, constitute the fundamental variables of this automotive design phase. Thermal Aerodynamics Design (TASE): Thermal airflow dynamics analysis, which guides automotive design activities, is a specialized field encompassing numerous variables, from fuel efficiency to steering and traction coefficients among designed alternative body structures (Figure 14). As illustrated in Figure 14, this scientific approach, which began with wind tunnels, is now being implemented through computer analysis.

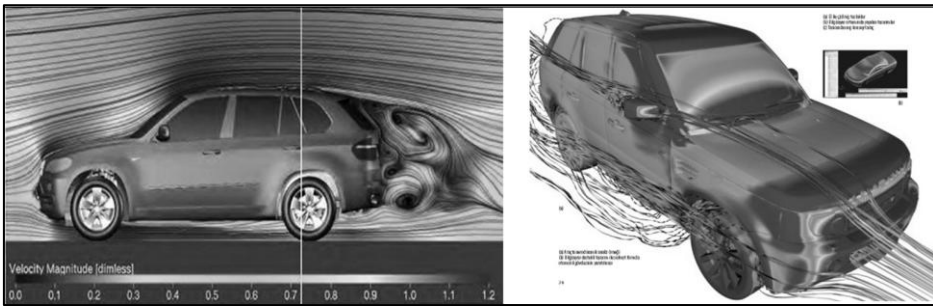


Figure 14. Thermal aerodynamics design phase (Weber, 2009).

Thermal aerodynamic measurements begin the automotive design phase, working on a clay model of the vehicle and supporting its form structure (Figure 14). Furthermore, thermal aerodynamic calculations shape the vehicle structure under physical measurements in the wind tunnel, while analyses continue in the computer environment (Figure 14). Real-Time Rendering (RT): This is the automotive design phase that allows for the simultaneous use and immediate experience of new vehicle design alternatives in a computer environment, using 3D virtual images, using specialized equipment (Figure 15). As illustrated in Figure 15, this is the design phase that begins after the 3D CAD model of the new vehicle has been developed.



Figure 15. Real-Time render phase (Weber, 2009).

The Real-Time Rendering (RT) phase, illustrated above in Figure 15, involves customer and company management in the interim and main approval stages of the automotive design process (Figure 15). Therefore, during the RT phase, manufacturing investment approvals are granted based on realistic final images of newly designed parts and assemblies for which the automotive design processes have not been completed or produced (Figure 15). Rapid Prototype (RP): This is the process of creating a new part or vehicle model defined in the digital coordinate system of a 3D CAD vehicle model in a physical environment (Figure 16). Its difference from a CNC machine is that, instead of processing a solid block material by emptying it with a milling machine, the model is created by melting plastic-containing material according to the coordinate system and knitting it, as shown in Figure 16.



Figure 16. Rapid Prototype (Tovey, 2012).

The rapid prototyping phase, illustrated in Figure 16, is carried out for the physical inspection of parts resulting from the automotive design phase or for their compatibility with other new parts (Figure 16). Furthermore, rapid prototyping machines are diversifying today due to their rapid development, providing outputs close to actual production parts (Figure 16). Functional interior-exterior vehicle mock-up (MP): This is the prototype manufacturing phase of a functional new vehicle model created by assembling new vehicle parts from rapid prototype manufacturing, along with parts from an existing production vehicle (Figure 17). As illustrated in Figure 17, the mock-up process, used to observe the new whole emerging in automotive design activities, is created following interdisciplinary acceptances and approvals within the product development flow.

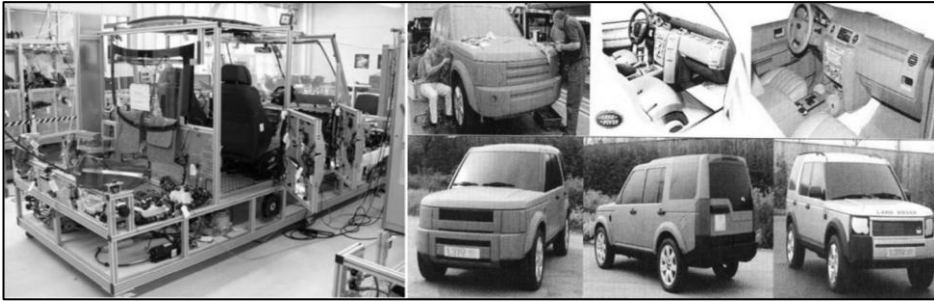


Figure 17. Functional interior-exterior vehicle mock-up phase (Tovey, 2012).

The automotive design process is completed or undergoing modifications. Vehicle interior and exterior functional prototype/mock-up manufacturing is carried out to test the compatibility, ergonomics, connection details, and similar usability and assembly of newly designed parts (Figure 17). The interior and exterior functional prototype/mock-up phase, shown in Figure 17, coordinates interdisciplinary work in a physical environment. Vehicle body design (Body in White (BIW)): This phase involves the computer-aided design of the forces and loads affecting the new vehicle's exterior structural structure using finite element analysis, fluid mechanics, and similar methods (Figure 18). As illustrated in Figure 18, the reliability of the vehicle's basic structural structure is carried out alongside design activities, down to the joints and details of the exterior body design.

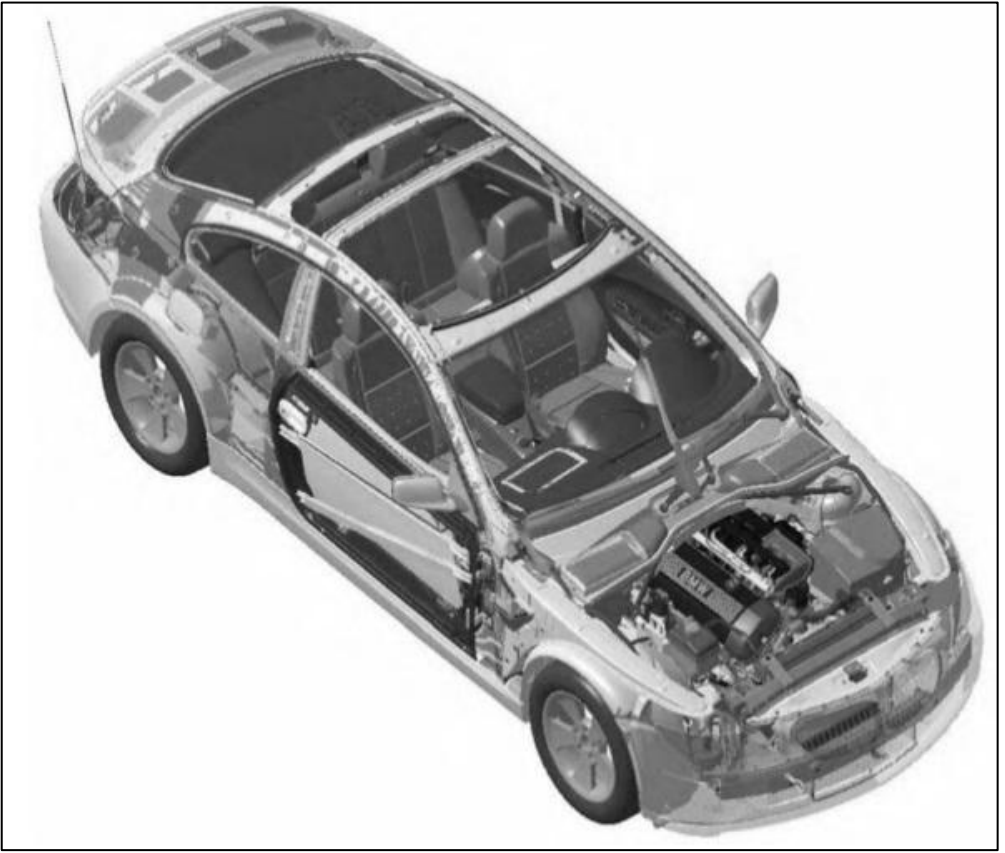


Figure 18. Vehicle body (BIW) design phase (Weber, 2009; Parker, 2018).

The BIW process, where the main body and body enclosures of a new vehicle are determined during the automotive design phase, is one of the fundamental steps in which interior and exterior trim parts enclose the engine chassis or model the driver and passenger areas (Figure 18). The BIW phase is one of the final steps in the automotive design process, where the production mold manufacturing process is transitioned to mass production (Figure 18). Virtual assembly design (Digital Pre-Assembly Design (DPA)): This is the phase where the assembly of the new vehicle parts undergoing design activities is tested in a virtual environment according to the sequence of workstations on the production line (Figure 19). As illustrated in Figure 19, this includes testing the assembly of the new vehicle parts on a 3D production line in a computer environment, as well as testing under various variables such as assembly weights, assembly times, assembly sequences, and so on.

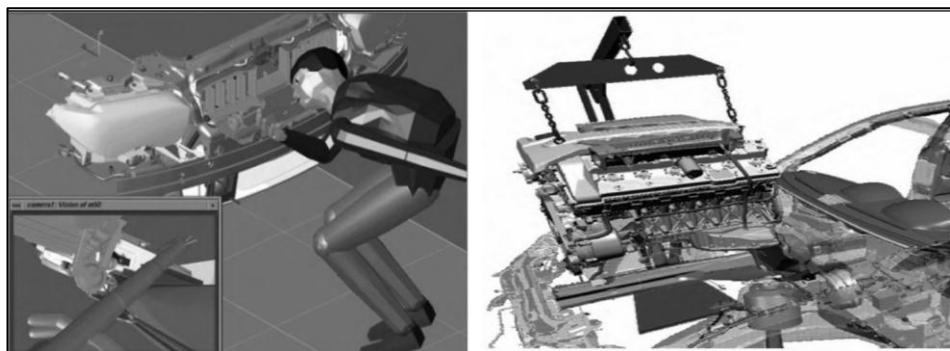


Figure 19. Virtual assembly design phase (Weber, 2009).

The virtual assembly phase, where new parts and vehicle assembly line data emerging from the automotive design process are generated and tested, is structured according to defined assembly worker standards (Figure 19). The virtual assembly phase utilizes time-based approaches that identify additional measurement components for automotive design, mass production, or assembly line problems (Figure 19). Regulation and Homologation (RH): This is the certification phase for commercialization of newly developed vehicles under the minimum "safety, comfort, and environmental" acceptance criteria and conditions established by the countries where they will be sold (Figure 20). Regulations, illustrated in Figure 20, are prepared by the industry ministries of the countries in question, and to protect consumers, new vehicles entering the market are tested and certified at international test centers. International regulations (CE, ECE, EEC, SAE, REG, etc.) constitute the minimum acceptance criteria for new vehicles (Figure 20).



Figure 20. International regulations and certification phase (Weber, 2009).

Designing, developing, and documenting new vehicles suitable for target markets are structured within product development processes (Figure 20). Therefore, ensuring the control and continuity of these acceptance criteria throughout the automotive design phase is crucial for the commercialization of the new product (Figure 20). Although the stages identified in the literature and identified in fieldwork and participant interviews with experts within the automotive design phases differ in name across automotive industry companies, their functional areas of study are common. In the research model, automotive design stages are modeled under the 20 steps listed above. The rapid transition of new product development and design stages to the computer environment, and the methods used for prototype manufacturing or prototype work within digital automotive design activities within the virtualized process, are revealed in current automotive industry research (Singer, 2018; Chung, 2018; Hirz, 2003). In addition, alternative new automotive design outputs directly affect new product development performance and, as a result, provide important orientations in the development process as they form customer perception in practice of new vehicle project targets to enter production (Jiang, 2015; Varga, 2015; Maropoulos, 2010; ElMaraghy, 2013).

Research Method

The research population consists of automotive design professionals working in the automotive main and sub-industry in our country. Therefore, the qualitative research method used in this study helps uncover the underlying reasons behind a phenomenon about which very little is known (Frank, 2005). Following the literature review in the preparatory phase, the terminology, concept, and process structure of automotive design revealed through one-on-one case interviews guided the study toward qualitative research methods. The qualitative methods used in the subsequent stages of the research, along with observation, interview, and case study findings, were determined to guide the data evaluation. A detailed literature review was conducted to identify the research questions and purpose. It consists of defining a problem, the problematic, and defining the objective structured within the possible outcome boundaries. The research objectives are directly proportional to the scope of the problem. Following the literature review, the research began with a pilot study (with company managers) and one-on-one interviews (with company experts) within the qualitative methods to initially test the information obtained. Given the study's holistic approach, qualitative methods were chosen to achieve in-depth results within a narrow area, excluding the initial phase of the research and the analysis of the final findings. A review of the study as a whole reveals the use of qualitative research methods. The qualitative verification analyses that form the comparative structure of the research were tested against market data from official government statistics.

Research Model and Findings

A fundamental research finding is that the component surfaces that form the main form of a new vehicle are processed along with conceptual values, including air resistance, active and passive safety effects, connection details, and similar stages and requirements, prior to or during the automotive design process. The concepts that constitute the automotive design flow and stages are structured within the entire new product development process (Table 1). Another research finding is that modifications continue after the control and design pre-manufacture phases of the limiting values of these approaches on the new design vehicle. The automotive design and new product development process stages in Table 1 are intertwined within the basic flow, providing continuity and oriented towards common goals. The resulting table regarding the flow that creates this vehicle design is attached (Table 1). Table 1 does not include the sections and stages that provide input before automotive design.

Table 1. Automotive design stages for the new product development process.

	Automotive Design Processes	Automotive Company						Stage	Software	Trade
		AC1	AC2	AC3	AC4	AC5	AC6			
1	2D Doodle Design	+	+	+	-	-	-	AD	A.C.- A.D.- P.S	E.
2	2D Skecht Design	+	-	+	+	+	+	AD	A.C.- A.D.- P.S	E., G.
3	2D Technical Drawing	+	+	+	+	+	-	PD	A.S.- D.C.-S.W	E., T.
4	2D Vehicle Architecture	+	+	+	-	-	-	AD	A.C.- A.D.- P.S	E., G.
5	3D Clay (Mud) Model	+	+	-	-	-	-	PD	G.C.-D.C.-N.X	E., H.,S.
6	3D Power-Train Design	+	+	+	+	-	-	PD	G.C.-D.C.-N.X	E., M.
7	3D Cost Accounting	+	+	+	+	+	+	AD	A.S.- D.C.-S.W	E., M.
8	3D Interior-Exterior Design	+	-	-	-	-	-	PD	S.C. - V.R.	E., M.
9	3D Body in White (BIW)	+	+	+	+	-	-	PD	G.C.- D.C.-N.X	E., M.
10	3D Virtual Render (Real Time)	+	+	+	+	+	+	AD	D.C.- R.C.- S.W	E., M.
11	3D Interior-Exterior Mock-up	+	+	+	+	+	-	PD	R.C.- D.C.- S.W	E., M.
12	3D Virtual Assembly	+	+	-	-	-	-	PD	D.C.- N.X.-S.W	E., M.
13	3D A-Class Surface	+	+	-	-	-	-	AD	A.S. - D.C	E., T.
14	3D Rapid Prototype	+	+	+	+	+	+	AD	R.H – D.C	T., M.
15	3D Media Presentations	+	+	+	+	+	+	AD	G.C.- D.C.-N.X	E., M.
16	3D Vehicle Package	+	-	-	-	-	-	PD	D.C.- R.C.- S.W	E., M.
17	3D Thermal Aerodynamics	+	+	+	+	-	-	AD	R.C.- D.C.- S.W	E., M.
18	3D Vehicle Ergonomics	+	+	+	+	+	+	AD	D.C.- N.X.-S.W	E., M.
19	3D Interface Design	+	+	+	+	+	-	AD	A.S. - D.C	E., T.
20	3D Regulation& Homologation	+	+	-	-	-	-	PD	D.C.- R.C.- S.W	E., M.

Abbrev	Software	Abbrev	Software	Abbrev	Trade/ Occupation
A.C.	Autodesk Alias Concept	N.X.	Siemens Unigraphics	E.	Industrail Design
A.D.	Autodesk Alias Design	R.C.	Rhinoceros	T.	Technical Drawing
P.S.	Adobe Photoshop	G.C.	Geomagic Cimatron	H.	Heykel Sanatçısı
A.S.	Autodesk Alias AutoStudio	V.R.	Chaos Software VRay	G.	Grafik Sanatçısı
D.C.	Dassault System Catia	K.S.	KeyShot	S.	Seramik Sanatçısı
S.W.	Dassault System Solid Works	S.C.	Autodesk Show Case	M.	Makine Engineering

Abbrev	Stage	Abbrev	Stage
AD	Automotive Design Process	PD	New Product Development Process
AC	Automotive Company	AMC	Automotive Supplier Company

As stated above, while the 20 defined stages appear sequential in the field studies, returns to completed steps were observed after the stage transition (Table 1). Therefore, no information regarding the completion values or maturity of the automotive design process was found in the field studies.

Research Results

The success of new vehicle product development or design efforts is determined by systematically verifying project objectives and the dynamic structure used to achieve these objectives, and is measured by market penetration or acquisition. This research reveals the industrial design profession and its impact within the various automotive design and product development processes implemented in automotive companies. Therefore, a scientifically based approach to the automotive design workflow was established after identifying

innovation requirements for the new product development process. The fundamental processes that align the developed vehicle with the functional structure that meets customer needs within the automotive design flow or translate these new functional requirements into design parameters were revealed. The importance of automotive design parameters, their position in the flow, and the product life cycle were confirmed through study analyses, as seen in Table 1 above. Furthermore, the steps corresponding to the automotive design stages, terms, and concepts listed below are presented sequentially in Table 1 above and Table 2 below. Therefore, Table 2 presents the main vehicle development steps up to the automotive design stages, along with the interaction with the new product development process and the steps that are common or matched in the literature.

Table 2. Basic process concepts and terms in automotive design phase.

New Product Development Process								
Body in White Phase (BIW)		Power-Train Phase		Exterior Trim Design Phase		Interior Trim Design Phase		
Automotive Design Stage								
Doodle Skecht	2D Concept Styling	Clay Model	Media Present	Dijital Clay & CNC Clay	3D CAD Model	Rapid prototype	Interior/ Exter. Mock-Up	Virtul.Ass m.
New Product Development Stage for Automotive Design Process								
Vehicle Architect	Vehicle Ergonomics	Vehicle Packag e	Vehicle Regulation	Virtual Render	Thermal Aerodynamics	Vehicle Homologation	Driver Interfac e	A-Class Surface

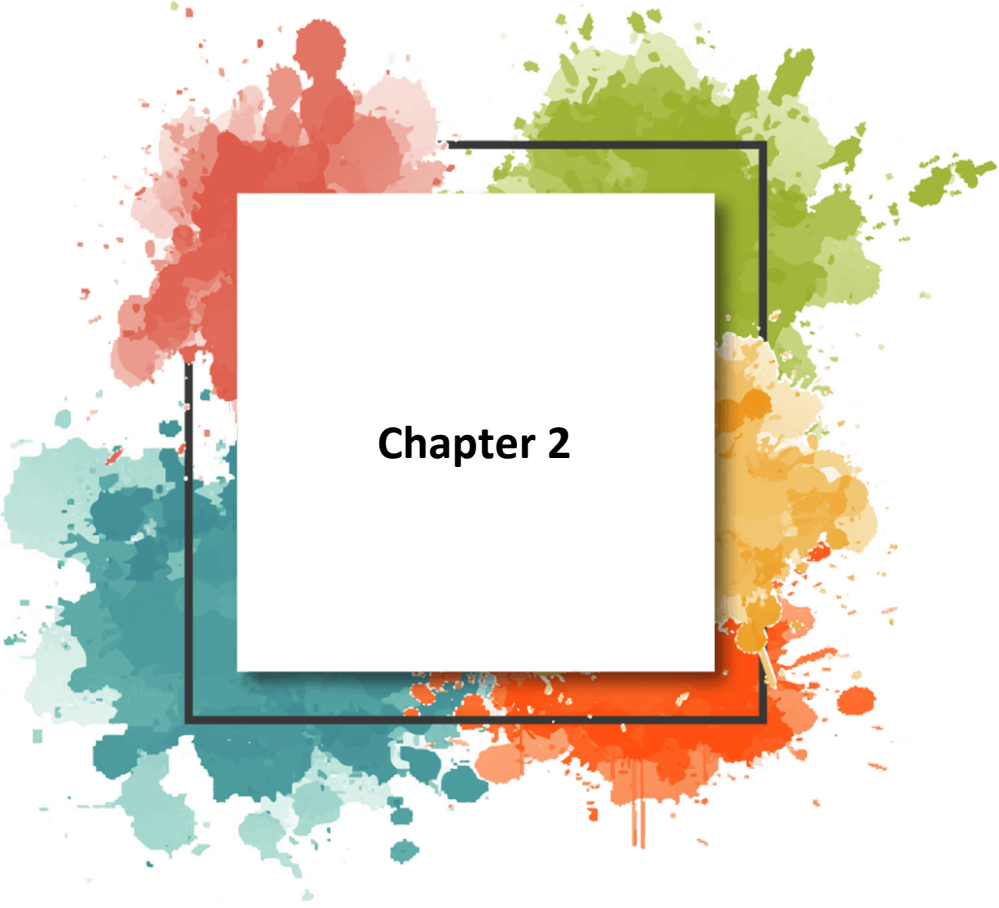
As presented in Table 2, the vehicle design in the research is the flow steps that define and plan the conceptual design structure, including its place within the product family, vehicle class, main and intermediate modules, versions, and similar values. As presented in Table 2, the automotive design process defines the structural dimensions of the newly developed vehicle, its position within the product range, along with its proportions within the product range, and the common infrastructure platform or components with products in the existing production line (Table 2). This approach is evident in the determination of project objectives or project acceptance criteria prior to the automotive design stages of the new product development process. On the other hand, when we examine the fundamental structure formed by the automotive design stages and the new product development processes, the influence of different concepts, steps, or variables is evident (Table 1). Furthermore, it has been observed that the design

definition of the new vehicle product is linked to the new product structure and new process research, as well as the new product development flow.

Acknowledgements: My article supports Fuat Ali Parker's 2018 thesis research and creates a reference for new process design studies.

REFERENCES

- Chung, W. C.** (2018). The Praxis of Design: Framing, Making, Doing, and Defining. *The Praxis of Product Design in Collaboration with Engineering*. 4, 37-53.
- ElMaraghy, H., et al.** (2013). Product variety management. *CIRP Annals, Manufacturing*. Manufacturing Competitiveness and Economic Sustainability. 1104, 1-7.
- Frank, A. W.** (2005). What Is Dialogical Research, and Why Should We Do It. *Qualitative health Research*. 15, 964-974.
- Hirz, M., Stadler, S., Prenner, M., Mayr, J.** (2013). Aerodynamic Investigations in Conceptual Vehicle Development Supported by Integrated Design and Simulation Methods. *Proceedings FISITA World Automotive*. 195, 787-799.
- Jiang, H., Kwong K.** (2015). A methodology of integrating affective design with defining engineering specifications for product design. *International Journal of Production Research*. 53, 2472-2488.
- Maropoulos, P., Ceglarek, D.** (2010). Design verification and validation in product lifecycle. *CIRP, Manufacturing Technology*. 59, 740-759.
- Paker, F. A., Alppay, C. and Sertyesilisik, B.** (2018). Use of the AHP Methodology in Vehicle Design Process Dynamics: Determination of the Most Effective Concept Phases for the New Automotive Product. *Journal of Transportation Technologies*. 8, 312-330.
- Singer, C.** (2018). *Methods for Change Management in Automotive Release Processes*. Springer, Automotive Systems Engineering. 2, 31-58.
- Tovey, M.** (2012). *Designer's Role in the Automobile Industry*. Journal of Transport Design. Routledge Publishing. New York, USA.1-363.
- Varga, B. O., Mariasiu, F., Moldovanu, D., Iclodean, C.** (2015). Principles of Modeling and Simulation Processes. *Hybrid Vehicles. Green Energy and Technology*. 1, 1-8.
- Weber, J.** (2009). *Automotive Development Processes. philosophy, approaches and empirical explorations*. Springer Publishing, Berlin, Germany, Heidelberg. 1-312.



Chapter 2

The Impact of Industrial Design Processes on Automotive Design Stages

Fuat Ali Parker¹

The primary objective of this research, along with a review of current literature on industrial design processes occurring in the automotive industry, is to examine its impact on automotive design and its role in its development within the defined study boundaries. Therefore, the automotive design profession and its stages, as defined or existing within industrial design processes, its position in the new product development process, and the changes it experiences within the basic flow were examined in-depth using a qualitative case study. In addition, a literature review specific to the research topic is structured using a case study methodology to analyze the historical development of the stages and concepts involved. Automotive design stages, created through industrial design processes in automotive manufacturing applications, emerge as the most important component of the new product development flow, a complex and intense interdisciplinary chain of activities. In this sector, each successive step involves designing the final new automotive product, in collaboration with industrial designers, within the scope of the various disciplines and scientific approaches within the main product development flow, and then moving on to the next product family. The automotive design flow steps covered in the research, along with the entire chain of sequential steps within the industrial design process, fall under the new product development process. Therefore, all stages within the new product development process, from the conception phase of a new automotive product to the emergence of the final vehicle concept, model the application and working environment of industrial design processes or automotive design phases. The fact that the components of the new vehicle's main structure and assembly, as designed, fulfill their functional duties in every aspect and under every usage scenario, constitutes the fundamental parameters of these phase transitions and also reveals the background of the research. When approaching the research from this perspective, the current framework of interdisciplinary approaches shapes the final new product design through a series of virtual and physical studies in a computer environment, based on the initial knowledge, values, and goals of the designed new vehicle. Furthermore, it was recognized that micro-level research topics within the scope of the study could also yield significant competitive advantages.

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Keywords: industrial design processes, automotive design, automotive industry, and design stages.

Introduction

The initial stages of the new product development process, where industrial design and automotive design work are carried out together in the automotive industry, along with the role and targeted new product and technology outcomes, indicate a process structure open to improvement in companies facing intense global competition. The automotive design stages within the product development process define a company's new vehicle product strategy, and therefore its global or local market needs, through multifaceted approaches, guiding it within a broad knowledge network (Kato, 2007; Griffin, 2018; Rodriguez, 2005). Along with new automotive design stages, examining the impact of industrial design on process development in the application field or assessing the value of different process variables under scientific approaches can have significant consequences for the new product's market success. Therefore, the fiercely competitive environment experienced in the global automotive industry creates a connection between the role and position of automotive design stage expertise within the current industrial design process (Xu, 2018; Song, 2010; Seidel, 2014). The strong interaction between industrial design and automotive design studies in automotive industry applications, as depicted in Figure 1, results in the determination of a multidisciplinary flow structure or the process-oriented positioning of variables (Paker, 2018; Mozota, 2005; Nordlund, 2016). Furthermore, the study in Figure 1 reveals the distinct advantages of single-alternative vehicle design compared to multiple-alternative automotive design in the traditional industrial design process (Nordlund, 2016).

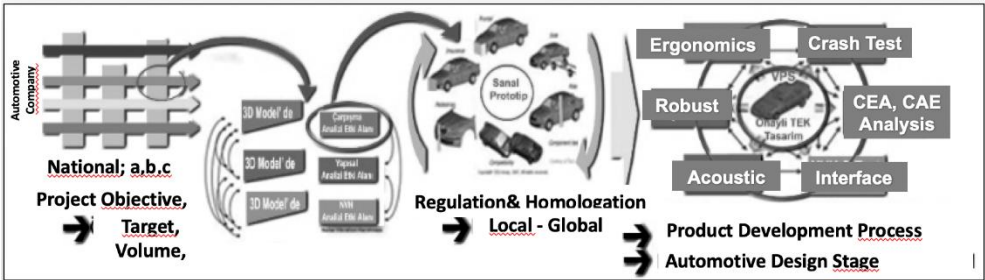


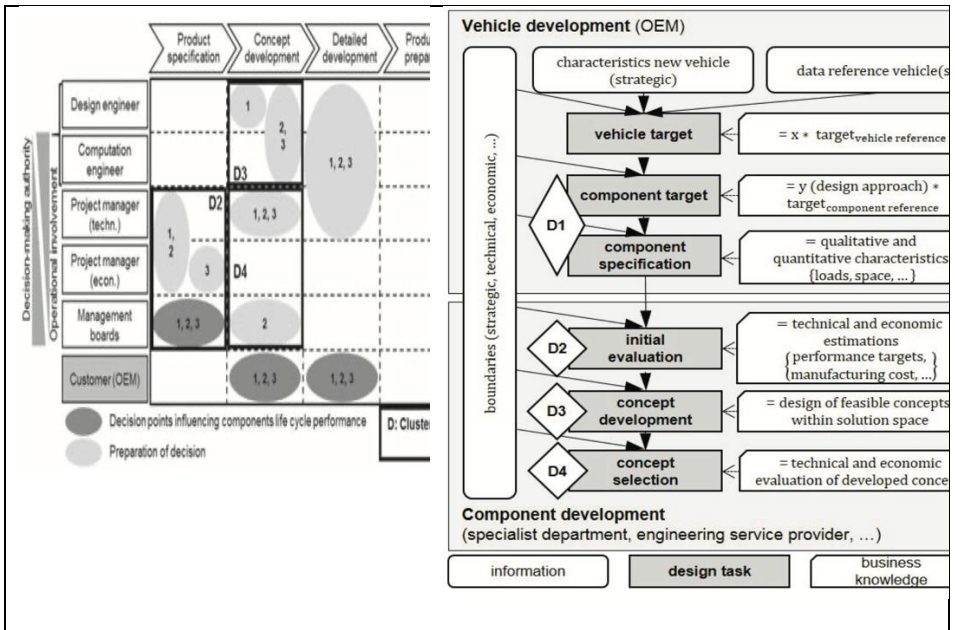
Figure 1. Automotive design approach on industrial design discipline (Nordlund, 2016).

Interdisciplinary automotive design flow analysis, focused on the industrial design profession and forming the basis of this research, has been widely researched using different scientific approaches (Figure 1). However, Figure 1 above suggests that conducting structural vehicle testing and analysis solely on a single conceptual vehicle design model will linearly direct industrial design activities, in order to mitigate the impact of iterative flow modifications and consolidation biases on project time management in interdisciplinary automotive design approaches (Paker, 2018; Nordlund, 2016). Furthermore, feasibility studies conducted to obtain initial information before the new product development process (investment, product cost, and market structure) led to product architecture and feasibility studies (Figure 1). Furthermore, as Figure 1 illustrates, the foundation of the initial concept designs after the initial automotive design phase is structured within market and user experience research, in accordance with homologation, regulations, and international specifications. Therefore, the interdisciplinary feasibility of concept vehicle designs, cost targets, or product architecture-commonality decisions are conducted within the framework of feasibility decisions within the initial industrial design processes (Figure 1).

In contrast, current scientific approaches have led to the emergence of an integrated industrial design flow that integrates or fosters collaboration among interdisciplinary new product development professionals within automotive design phase specialties, where they perform the "design-modeling-simulation-verification" activities (Paker, 2018; Nordlund, 2016; Tucker, 2011). It also examines industrial design specialties and automotive design techniques in three dimensions: visualization-based flow systems, collaborative design-oriented collaborative systems, and a concurrent design-based system proposal (Liu, 2018). The real-time online automotive design flow, where different designers using different systems create three-dimensional digital models of new automotive products, or where different disciplines can make instantaneous changes to the same virtual vehicle model, creates new collaboration approaches along with the formation of vehicle design boundaries (Li, 2019). Similarly, it is suggested that industrial designers can achieve success in global competition through the use of 'tools' employed in similar product family vehicles, under new boundaries within the knowledge repository internalized by automotive industry companies, based on a virtual or digital product model-based industrial design workflow (Paker, 2018; Styliadis, 2016). In addition, it is stated that the heterogeneous industrial design flow, together with product architecture, can increase efficiency in studies of digital product model-based disciplines (3D vehicle model, 3D structural analysis, 3D crash tests, 3D rollover analysis, etc.) (Tucker, 2011; Freddi, 2019; Hou, 2017). Along with the studies above, new autonomous and artificial intelligence-focused industrial design specializations

are remodeling the existing automotive design stages or the basic flow of industrial design and product development. The discipline of industrial design has evolved over time, gaining importance in its strategic and hierarchical role within new product development processes within major automotive manufacturing companies. The need for a new automotive design flow that will generate development and design alternatives for new vehicle products within targeted values, or evaluate these final alternatives under intense competition (across customer, market, production, and similar dimensions), and make the right choices, is being actively pursued within automotive companies (Hou, 2017).

The success of new product development studies in the automotive industry is calculated by determining performance targets and the dynamic industrial design process structure used to achieve these targets under systematic steps, and by global market expansion or gain. Therefore, these scientific studies compare the different automotive design stages implemented in the main and sub-industry manufacturing companies, with the new product development process structure they are linked to, to determine how more efficient and higher market success can be achieved. Furthermore, the identification of innovation requirements in the automotive industry and its subsequent implementation have led to the creation of different scientifically based approaches to the new product development workflow (Figure 2). As presented in Figure 2, processes that align developed customer needs with the functional structure or translate these functional requirements into industrial design parameters are proposed (Suh, 2001; Kaluza, 2016; Göhler, 2018). The importance sequence or efficient flow position of new automotive design parameters is realized through decision-making analyses of the current product life cycle as seen in Figure 2.



As shown in Figure 2, the industrial design stages and new product design objectives within high-value creation are matched with automotive design steps that can support or overlap with lower-level subrequirements and variables, thus optimizing the flow of the basic steps (Kaluza, 2016). Furthermore, in Figure 2, the numbers "D1, D2, D3, D4" represent the automotive design stages where industrial design objectives are established, while the numbers "1, 2, and 3" identify the decision maker and decision indicator that define the product lifecycle. On the other hand, the method proposed in Figure 2 is a theoretical approach that will reveal decision-making criteria for all automotive design stakeholders and industrial designers involved in the product development process. Along with new definitions of automotive design stages, similar approaches to flow efficiency include automotive design process analysis, stage thresholds for quality and basic vehicle design stages in the industrial design flow, and studies highlighting the importance of design activities within the product development process related to industrial design stages for manufacturing (Nordlund, 2016; Varga, 2015; Baxter, 2007). Figure 3 categorizes design research into three stages (micro, meso, macro) and four approaches (theory, writing, managerial, and analytical) (Wynn, 2018). Furthermore, when the three levels of literature in Figure 3 are examined, the micro level (stage development) focuses on the stages of the industrial design process and the common task flow of these stages, while the mid-level

(managerial development) focuses on the basic task flow from the beginning to the end of the industrial design process. The macro level (conceptual development) defines the design concepts created by product and industrial structures (Figure 3).

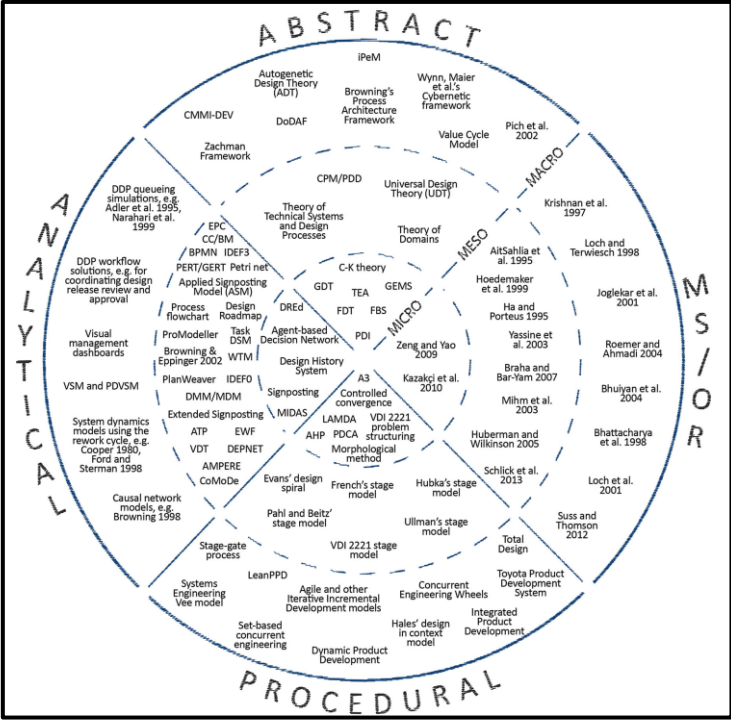


Figure 3. Literature map of automotive design research (Wynn, 2018).

Furthermore, as depicted in Figure 3, the theoretical approach model from four different literature tiers, along with research that incorporates a specific theoretical perspective on the design process, directs the development of writing to the results of face-to-face interviews and in-depth case studies. On the other hand, managerial flow models, while matching the criteria that affect the practical counterpart of the problem within the industrial design process, reveal analysis, synthesis, and case studies under the input of information that forms analytical mathematical models (Wynn, 2018). On the other hand, in addition to the approaches mentioned in Figure 3, the industrial design process is diversified by matching the matrix structure related to the problem and task dependency determined in the industrial design stages with the product development flow or by using the simultaneous flow in automotive design and the information dissemination that occurs in common step transitions.

Research Method

The selection of the study field and research population is influenced by the automotive manufacturing industry, a country's economic conditions being a determining factor at both the national and international levels. Therefore, conducting the research on automotive design processes with employees from automotive main and subcontractor companies in our country stems from the goal of ensuring widespread dissemination of the study's outputs. On the other hand, the qualitative research method used in the study is based on the premise that in-depth, debatable knowledge should originate from the core of the industry's competitive approaches. A detailed literature review, followed by one-on-one case interviews, was used to identify specific current automotive design terms, concepts, and processes, again using a qualitative study design. Furthermore, each phase of the study, or the next step plan, was synthesized with the findings of observation, interview, and case study using the initially chosen qualitative method approaches. The basic research proposal and questions, or the study objective, were developed after a detailed literature review. In other words, identifying the research problem or problematic, or defining the purpose and scope along with the potential study area and research boundaries, all develop within the framework of the basic hypothesis. Therefore, the fundamental problem or scope of the study, along with its research objective, is addressed under the methodological proposal approach. Examining the flow of the study, the information obtained after the literature review was tested at an initial level using qualitative methods, including a pilot study (company managers) and one-on-one interviews (company expert employees). On the other hand, considering the inductive approach of the study, in order to achieve in-depth results in a narrow field, the initial variables or possible findings of the research have brought the use of other qualitative methods to the fore, apart from structured analyses. Therefore, when reviewing the entire study, it was realized that, although the initial qualitative research methodology was time-consuming, observation and experience in the field revealed or supported valuable results. The research's planned comparative structure and qualitative evaluation analyses were tested against national and international automotive manufacturing statistics.

Research Model

Looking at the fundamental structure of automotive design activities and new product development processes, the research model demonstrates the impact of various industrial design variables (Figure 4). Figure 4 focuses on the definition of a new vehicle product and its industrial design stages, the existing product family structure, and the fundamental link between existing parts or systems and the new product development flow in new technology adoption efforts.

	Automotive Design Stage in the Product Development Process		Automotive Company (project/month)						Stage	Trade
			AC1	AC2	AC3	AC4	AC5	AC6		
			48m	47m	48m	24m	23ay	24ay		
1	Strategic Project Managem.		+	+	-	-	-	-	PLM	ME, IE, RE
2	Regional Vehicle Manage.		+	-	+	-	-	-	PLM	ME, IE, RE
3	Vehicle Architecture		+	+	+	-	-	-	PLM	ME, IE, RE
4	Vehicle Platform Managem.		+	+	+	+	+	+	PLM	ME, IE, RE
5	Cost Accounting		+	+	+	+	-	-	MRP	ME, EE, TE
6	New Technology Adap.		+	-	-	-	-	-	CAD	EE, TE, CE
7	Autonomous Technolgy		+	+	+	-	-	-	CAE	EE, EE, CE
8	Elec.&Electro. Systems		+	+	+	+	+	+	EAD	EE, TE, CE
9	Power-Train		+	+	+	+	+	+	CAD	ME, IE, RE
10	Body in White (BIW)		+	+	+	+	-	-	CAD	ME, IE, RE
11	PD Purchase		+	+	-	-	+	+	ERP	ME, IE, RE
12	PD Assembly		+	+	+	+	+	+	MRP	ME, IE, RE
13	Interior- Exterior Trim		+	+	+	+	+	+	CAD	ME, IE, RE
14	Vehicle Package		+	-	-	-	-	-	CAE	ME, IE, RE
15	Vehicle Ergonomics		+	+	+	-	-	-	CFD	ME, IE, RE
16	Driver Interface Control		+	+	-	-	-	-	EAD	ME, TE, RE
17	Thermal Aerodynamics		+	+	-	-	-	-	CFD	ME, IE, RE
18	Under Body		+	+	+	+	+	-	CEA	ME, CE, RE
19	CAE, CEA Analsys		+	+	+	+	+	-	CAE	ME, IE, RE
20	Upper Body		+	+	+	-	+	+	CAE	ME, CE, TE
21	Prototype Mockup Verifica.		+	-	-	-	-	-	CMM	ME, IE, RE
22	After Sales		+	+	-	+	-	-	ERP	ME, EM, RE
23	Test and Analsys Managem.		+	+	+	+	+	-	CMM	ME, RE, CE
24	Regulation& Homologation		+	+	+	+	-	+	PLM	ME, EE, IE
Abbrev	Process	Abbrev	Stage Software					Abbrev	Trade	
Eng.	Engineering	CAD	Catia, Unigraphics, Solidworks,					ME	Mechanical Engineering	
Electk.	Electric	CMM	Cimatron, Simulator, Quindos					IE	Industrial Engineering	
Electr.	Electronic	CAE	Matlab, Patran, Nastran					EE	Electric engineering	
Reg.	Regulations	CEA	Ansys, Abaqus,					TE	Electronic engineering	
Hom.	Homoglations	CFD	Fluent, T-Gambit					CE	Computer Engineering	
Adp.	Adaptations	EAD	Proteus, Mentor Graphic					AE	Aircraft Engineering	
PLM	DS Enovia,	M-ERP	SAP, Oracle Agile, Dynamics,					RE	Mecatronic Engineering	
AC	Automotive Company				ASC	Automotive Supplier Company				

Figure 4. Automotive design stages.

The research is based on the fundamental premise that automotive design stages driven by the usage variables of a new vehicle concept under new functions can significantly impact the new product development platform between the customer domain and the process structure (Figure 4). Therefore, the model focuses on flow within the domain, unlike previous experimental methods used by industrial designers to test values or adapt new technologies. Furthermore,

they establish a common ground with new product development process expertise through the creation and validation of alternative solutions to fundamental design problems encountered in the process. Furthermore, these design model proposals or structural flow alternatives and solutions are realized through phase transition structures and interdisciplinary collaboration definitions that incorporate sufficient detail, incorporate innovation, and interact with tacit knowledge. Furthermore, automotive designers' shared systems-focused scientific approaches or competitive new ideas, along with product development experts, advance under the fundamental industrial design stages. Interdisciplinary approaches lead to the identification of goal-oriented features rather than measuring and structuring the construction of automotive design process steps or their differences from the industrial design discipline, or the interdisciplinary transitional steps within the new product development process. Figure 4 directs the definitions of automotive design parameters to the functional structure of the variables within the model that shapes the new vehicle concept. Furthermore, as depicted in the model in Figure 4, the automotive design process's sequential structure focuses on workflow and control rather than priorities. While process phases are driven by new concepts and technologies, themes aligned with the company's brand identity are open to identification throughout the process. Therefore, the fundamental stages that constitute automotive design activities can be reviewed through a collaborative evaluation with marketing and product development experts. The model described above and the arguments used are structured to measure the impact of vehicle form on component size using 2D sketches, 3D computer models, presentations, and prototype models, which are under the responsibility of industrial design experts.

Research Findings

The rapid transition of the industrial design process and new product development stages to the computer environment, or the virtualization of flow steps in digital automotive design activities, or the methods used for rapid prototyping or interdisciplinary development of design through virtual prototypes, were revealed during the field study of the research. As shown in Table 1, the validation of alternative new vehicle designs directly impacts product development performance. Consequently, it provides important direction in the development process, as it shapes customer perception of the project objectives for the new vehicle entering production. As shown in Table 1, during the clay model phase of the design activities, the main design surfaces of the new concept, based on the project objectives, are tested throughout the process, both in terms of the design's form effect and its engineering (aerodynamic) value.

Table 1. Stage transition flow in the automotive design process.

		Automotive Design Process				Industrial Design Stage						
Product Development Process	Proj Prepering	Market and Customer Research (User Experian Research)										
		Vehicle Architecture		Product Platform Engineering		Company Management		Project Plan				
		Fizibilite		Fizibilite								
		Project Plan		Vehicle Benchmark- TearDvn								
		Project Management		Vehicle Platform Management								
	Automotive Desg	2D Doodle - Skcht		2D Doodle - Skcht		2D Skech		2D Styling				
		2D Styling		2D Styling		2D CAD		2D CAD				
		2D Teknical Drawing		2D Teknical Drawing		2D Presnt.		3D CAD Model				
		2D Media Presantation		3D ¼ Clay Model								
		3D Clay Model		3D Dijital Clay&CNC Clay								
		3D Dijital Clay&CNC Clay		3D CAD model								
		3D CAD Model		1/1 Clay model		3D Rapid Prototype		3D CAD Model				
		3D Virtual Prototype		A class 3D CAD surface								
		3D Rapid Prototype		1/1 Interior-Exterior Mockup								
		3D Interior-Exterior Trim		3D Virtua Prototype								
		3D Interior-Exterior Mockup		3D Virtua Presentation		3D Interior-Exterior Trim		3D Interior-Exterior Trim				
		3D Virtual Assembly		3D Virtua Assembly								
		A Class Surface – 3D		3D Prototype								
		3D Homoglation & Regulations		3D Homoglation & Regulations		3D 3D Homoglation & Regulations		3D 3D Homoglation & Regulations				
		AUTOMOTİVE DESIGN STAGE FOR THE PRODUCT DEVELOPMENT PROCESS										

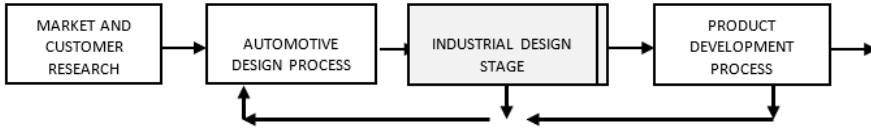


Table 1 describes the new product development process in the automotive manufacturing industry, along with the basic product family features of an existing vehicle model, and the different stage activities that enable the formation of new automotive product design targets or new design and technology concepts together with the application needs. Furthermore, as presented in Table 1, since the definition of new technology concepts that constitute the working knowledge of automotive design activities must take into account various or interdisciplinary conflicting boundary conditions and requirements, the emerging new vehicle concept has created common interdisciplinary design steps with different and new specializations. Additionally, testing or controlling the development that occurs in the later stages of the automotive design phases leads to significant losses in the new product development process. Therefore, in automotive design activities where the initially determined design goals and concepts are shaped and formed, carrying out control studies of the point reached by the design can provide positive value creation for the new product development process (Table 1). In today's product development approaches, the sharing of information between

computer-aided design (CAD) and computer-aided engineering (CAE) disciplines in the same digital environment allows for design control or determination of control parameters to occur in the early stages of the new product development process. Design goals and activities at the beginning of the product development process are defined with initial ideas, sketches, specifications, and new technologies and concepts. Thus, the new 3D CAD vehicle model guided by the design boundary conditions is created with control parameters in the design stages under the surface geometries. Therefore, the new vehicle concept created under the initial design targets is again tested under the initial values and targets. Therefore, new vehicle design testing studies under automotive design activities or repetitive or trial-and-error studies in similar steps that create high costs: clay model, rapid prototype, functional prototype (mock-up), virtual prototype, etc., constitute a time-consuming and variable structure.

Research Results

As stated in Table 1, the determination, separation, examination and control or acceptance under certain tolerances of the initial new vehicle design targets that constitute the product life cycle, reveal the final vehicle design acceptance and approval parameters that can be achieved by the interdisciplinary product development process in question. As stated in the introduction and model of the study, the suitability of newly designed vehicles, which are newly produced in the automotive manufacturing industry, for all kinds of customers and possible usage conditions, and the evaluation of each new concept in the automotive design stages by product development experts under the scientific approaches within the founding industrial design discipline are the fundamental research findings. Another research finding is that the most important variables that save time and cost in the basic and new product development process are the early addition of the information used in the adaptation of each new concept and technology processed in the automotive design stages to the main flow, which will make interdisciplinary functional boundary condition and tolerance values or control and approval studies successful. However, determining new vehicle design criteria and control parameters equivalent to diverse customers and possible usage scenarios, or controlling the boundary conditions of the new vehicle concept under global competition, spreads the functions and adaptation of the new technology into process steps. Therefore, the calculation of road loads, finite element analyses, evaluation of stress and torsion or life analyses on the main structure, on a piece-by-piece and as a whole, on the conceptual vehicle structure, under engineering variables, modifications, and transfer of the boundary conditions created by the re-evaluation at the beginning of the project, observed in the field studies of the research, prevent modifications in the following process. In the research, industrial design discipline and process are

recommended for the initial setup of automotive design stages. Therefore, each new stage and concept in the automotive design process focused on industrial design discipline can prevent the repetitive structure in new product development phase transitions and transform the flow into a linear and integrated structure, as suggested in the research hypothesis. The left vertical columns of the flow structure in Table 1 show the automotive design stages and the matching right side shows the commonly used software and hardware, as can be seen. Therefore, it shows the interdisciplinary engineering studies that match the automotive design stages in the new product development process, and the new vehicle design control steps from whole to part or from part to whole in terms of the operation of the basic flow model. Design control or testing in automotive design activities is now carried out digitally in a virtual environment, with physical analysis and tests performed to determine the impact of the newly developed automotive product on each component formation within the whole or the component connection details of the whole and the basic product function.

Therefore, the automotive design stages transferred to the computer environment create important trends in the physical prototype development of the new vehicle product or in the testing and control review steps performed on the prototype vehicle or in the design decision steps. Furthermore, losses in phase transition approvals or modifications of virtual or physical vehicle prototypes developed for automotive design studies and their impact on new product development are overshadowed by otherwise high efficiency gains. The losses or gains in question within the entire flow are included under the development expertise on the prototype vehicle product. Automotive design stages that allow interaction with physical objects define how industrial designers interact with new vehicle products or solution approaches to new vehicle design problems with analyses appropriate to the industrial design discipline.

References

- Baxter, D., Gao, J., Case, K., et al.** (2007). An engineering design knowledge reuse methodology using process modelling. *Research in engineering design*. 18, 37-48.
- Freddi, A., Salmon, M.** (2019). Safety Assessment. *Design Principles and Methodologies*. 1, 97-125.
- Griffin, A., Langerak, F., Eling, K.** (2018). The Evolution, Status and Research Agenda for the Future of Research in NPD Cycle Time. *Journal of Product Innovation Management*. 1, 1-33.
- Göhler, S. M., Christensen, M. E., Howard, T. J.** (2018). Mechanisms and coherences of robust design methodology: a robust design process proposal. *Total Quality Management & Business Excellence*. 29, 239-259.
- Hou, W., Shan, C., Yu, Y., et al.** (2017). Modular platform optimization in conceptual vehicle body design via modified graph-based decomposition algorithm and cost-based priority method. *Structural and Multidisciplinary Optimization*. 55, 2087-2097.
- Kaluza, A., Kleemann, S., Broch, F., Herrmann, C., Vietor, T.** (2016). Analysing decision-making in automotive design towards life cycle engineering for hybrid lightweight components. *CIRP*. 50, 825-830.
- Katoh, H.** (2007). The Collaborative Digital Process Methodology achieved the half lead-time of new car development. *International Conference on Concurrent Engineering*. 14, 621-638.
- Li, T., Zhao, D., Zhao, J.** (2019). Construction of an Evaluation System for Automotive Interior Rendering Based on Visual Perception. *International Conference on Applied Human Factors*. 774, 146-157.
- Liu, Y., Liu, Z., Qin, H.** (2018). An efficient structural optimization approach for the modular automotive body conceptual design. *Structural and Multidisciplinary Optimization*. 58, 1275-1289.
- Mozota, B., et al.** (2005). The Impact of User-Oriented Design on New Product Development: An Examination of Fundamental Relationships. *Journal of Product Innovation Management*. 22, 128-143.
- Nordlund, M., Kim, S., Tate, D., Lee, T., Hilario, L.** (2016). Axiomatic Design: Making the Abstract Concrete. *Procedia CIRP Design Conference*. 50, 216-221.
- Paker, F. A., Alppay, C. and Sertyesilisik, B.** (2018). Use of the AHP Methodology in Vehicle Design Process Dynamics: Determination of the Most Effective

- Concept Phases for the New Automotive Product. *Journal of Transportation Technologies*. 8, 312-330.
- Rodriguez, K., Ashaab, A.** (2005). Knowledge web-based system architecture for collaborative. *Journal of Computers in Industry*. 56, 125-140.
- Seidel, V. P., O'Mahony, S.** (2014). Managing the repertoire: stories, metaphors, prototypes, and concept coherence in product innovation. *Orginal Scince*. 25, 691-712.
- Song, M. J., Nam, K. & Chung, K.** (2010). The Chief Executive's Influence on Corporate Design Management Activities. *The Design Management Journal*.3, 32-34.
- Stylidis, K., Rossi, M., Wickman, C., Söderberg, R.** (2016). The communication strategies and customer's requirements definition at the early design stages: an empirical study on Italian luxury automotive brands. *Procedia CIRP, Design Conference*. 50, 553-558.
- Suh, N.** (2001). *Axiomatic Design: Advances and Applications*. MIT Press, Pappalardo Series in Mechanical Engineering, New York, USA.
- Tucker, C., Kim, H., et al.** (2011). Predicting emerging product design trend by mining publicly available customer review data. *Proceedings of the 18th International Conference on Engineering Design (ICED 11)*. 6, 43-52
- Varga, B. O., Mariasiu, F., Moldovanu, D., Iclodean, C.** (2015). Principles of Modeling and Simulation Processes. *Hybrid Vehicles. Green Energy and Technology*. 1, 1-8.
- Wynn, D., Clarkson, P. J.** (2018). Process models in design and development. *Research in Engineering Design Review*. 29, 161-202.
- Xu, B., Cai, Y.** (2018). A multiple-data-based efficient global optimization algorithm and its parallel implementation for automotive body design. *Advances in Mechanical Engineering*. 10, 1-13.