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New Autonomous Vehicle Technologies Effect on Automotive Concept Design Stages

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Abstract

New road transportation systems solutions create significant changes in existing automotive manufacturing industry products and technologies, from design to use. The conveniences within the framework of new approaches brought by autonomous vehicle technologies primarily make individuals transition from driver duty to passenger and high-comfort alternative travel technologies. Therefore, the research: defining the path followed by the autonomous vehicle technologies, which lead to the development of the said new life model and automotive products within the future fiction, in the stages of designing new concept vehicles in practice or measuring the effect on the processes constitute important values for the future prediction of this sector. In addition, the research has focused on the effects of interdisciplinary studies at the automotive concept design stages, which are at the beginning of today's lean and new product development process, where innovation goals or technologies emerge with more concrete needs. New autonomous vehicle technologies and the main purpose of revealing the interdisciplinary studies created by new disciplines in the current automotive concept design stages make significant contributions to the optimization of the lean product development process and value creation. For this reason, the automotive manufacturing industry, which is on the eve of a major transformation with the said new autonomous vehicle technologies; determining the needs or sustainable position in the flow of digital perception and orientation systems; determining value creation criteria related to the functioning of automotive concept design processes or new acceptance criteria through one-on-one interviews in the field; constitutes the focus of the research. The research has examined the new interdisciplinary studies and effects of new autonomous vehicle technologies in the automotive concept design phase, which is the first step of lean product development, with local and global automotive industry company comparisons in operation. Therefore, the differences and similarities between the concept design stages of global automotive companies that are both co-developers of new autonomous vehicle technologies and manufacturing automotive products and local automotive manufacturing companies that only assemble them determine the future competitive structuring of the industry.

Keywords

Autonomous Vehicle Technologies, Automotive Manufacturing Industry, Automotive Concept Design, Automotive Design Process, Lean Product Development

1. Introduction

The concrete emergence of the idea of innovation, which is the basis of lean and new product development, depends on the automotive concept design phase and proficiency studies, which are at the beginning of the flow. Although the first thing that comes to mind here is the new product, the newly designed concrete object, interdisciplinary studies that can realize the vehicle functions or functions aimed by the innovation are in practice at the automotive concept design stage. The physical location of these autonomous technologies in practice creates new support technology requirements along with function needs. Today innovation has revealed the design of services along with products and technologies [1] [2] [3]. Therefore, autonomous vehicles, which have just started to be included in the automotive industry, have begun to materialize and become clear with their needs at the beginning of the lean product development process (automotive concept design stage), together with new technology installations. The word automotive concept design or design means creating a new plan or process, innovation, or creating a new function, system, technology, model, form, style, depending on the environment in which it is used [3] [4] [5]. This situation can be defined as the flow of creating innovation under a concrete main model by systematically defining the needs to shape the idea in line with a purpose or target. Industrial design engineering, specialization or industrial design discipline; It is positioned under the automotive design department, which is at the beginning of the lean product development processes in the automotive manufacturing industry, and maintains its importance in the competition with different units and intermediate processes that add value to the company [5] [6] [7]. Automotive manufacturing industry is the sector with the highest added value together with heavy global competition in terms of providing national and international sustainable socio-economic development. The high added value increase in the sector is related to being able to dominate new technology and change, to make original and new designs, to have redevelopment or variable production capability and knowledge. For this reason, in order to contribute to the realization goals of sustainable socio-economic development, systems that can only switch from production focus to new product design focus and create value can survive today. However, when the main reasons for the current lean product development practices in the automotive industry are examined, one is resource management and optimization, and the other is innovation and design management [3] [5] [7]. New product design or automotive concept design realized in the automotive industry drives innovation management, value creation and preservation in the entire process. Therefore, this discipline has an extremely widespread and dominant effect on both the parts of the automotive industry companies and the lean product development process. Product design continues to work on meeting or creating the needs and needs of individuals in general, and the discipline of automotive concept design performs the same task under autonomous vehicles. In summary, the design profession transfers this need and requirement back to the individuals as consumption within the boundaries of the "product" within the scope of a model as an innovation. Consumption turns into design with new needs, and design turns into consumption with innovations. The said cycle creates a dynamic structure or a cyclical process with production and consumption phases. Simplifying the new product development flow, which takes place in a repetitive and cyclical structure in today's conditions, optimizing innovation-oriented, is the process of transferring the innovation definitions to the automotive concept design discipline at the beginning of the process, and transferring the innovation back to consumption at the product boundaries with the same value in the final new product.

Therefore, the basic starting point of automotive design or product design is what the user expects or can expect from a new product [8] [9]. It is no longer considered sufficient for a newly designed product to fulfill its functional task in today's competitive conditions. Apart from this, the designer has to know, understand and determine what the user expects and make a design that fulfills its task in the appropriate possibilities. On the other hand, the act of design includes interdisciplinary processes and approaches in the automotive industry. Therefore, the design of a new product takes place in the lean product development stages, where multidisciplinary innovation with high time and investment in the automotive industry is preserved from the beginning to the end of the process. However, in order to survive under global competitive conditions, automotive industry companies must reduce their costs (design, development, test and analysis, manufacturing and supply, sales and marketing, etc.), at least keep them under control, increase their brand values and make their lives by delivering their products on time [3] [9] [10] [11] [12]. In addition, automotive industry companies in particular aim to design and develop new products by differentiating safety and reliability, durability and functionality with the preferable appearance of new products, ease of use or autonomous use, and to deliver these vehicles to the customers before their competitors. For this reason, due diligence in the automotive concept design stages, which are deeply affected by autonomous vehicle technologies, has important consequences for the creation and preservation of the innovation values of the envisaged lean product development process. The study has important information and findings that form an interface in the application of autonomous vehicle technologies together with the automotive design discipline of the sector. Another important subject that is emphasized is the structural comparisons related to the integration or competition of new product development studies led by the mergers and acquisitions that started in the automotive manufacturing industry. In addition, data were collected for due diligence on the performance and application possibilities of technology acquisition or creation in global and local automotive manufacturing industry companies. Therefore, the new approach that the research focuses on, how the automotive concept design stages create a workflow together with new autonomous technology applications, and the comparative examination of the said workflow in different company structures will make a positive contribution to the innovation applications of the next generation vehicles. The study primarily examined the automotive concept design phase definitions and publications on new autonomous vehicle technologies in the literature. In the following sections, the results of the synthesis together with the field research method and the one-to-one interview analyzes obtained from the field are shared.

2. Literature Review; Autonomous Technologies and Concept Design Stages

The second part of the research focused on the definitions of new autonomous vehicle technologies and automotive concept design stages in the literature. Therefore, this section is gathered under two consecutive sub-titles and shares the literature approaches specific to the subject. In addition, the new autonomous vehicle technologies, which are included in the first sub-title in the chapter, guided the research within the scope of one-to-one observation during the field studies. Automotive concept design stages, which are the second subheadings of this section, are the living stages and variables that have been observed both in the literature and during field studies. Therefore, the stage or stage definitions determined in the literature and observed in the field studies were evaluated over the whole process.

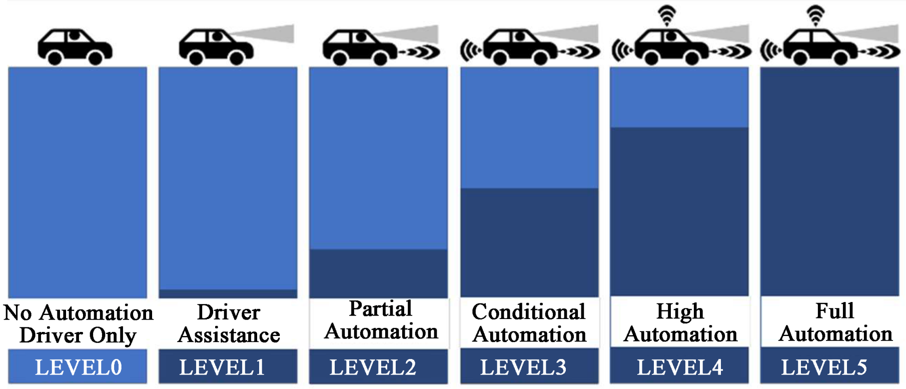
2.1. New Autonomous Vehicle Technologies

New autonomous vehicle technologies remodel the entire flow from the concept design phase at the beginning of lean product development to the pre-series production phase. Today, advanced simulation and virtual modelling techniques, software and hardware used by the automotive concept design discipline provide better optimization and integration of components involved in vehicle development [13] [14] [15] [16] [17]. Product lifecycle (PL), of autonomous vehicle technologies, the competitiveness of local companies also reveals the stages and results of original automotive design. According to the results of one-to-one interviews and joint analysis with the design and development managers integrated 3D vehicle modelling (Catia, Solid, Alias, etc.), new product design techniques and communication integration, together with the increase in user experience research and alternative use scenarios, the decrease in the need for physical prototypes, resource management, performance and cost provides gains. As autonomous vehicle designs become widespread, special applications for traffic-vehicle-communication-environment become more suitable, and the chance to include different vehicle concepts depending on their function and usage situations or driving environment increases. Therefore, depending on the changing, differentiating business models, in the long run, some automotive industry companies may choose to be a mobility provider and therefore control a larger part of the vehicle life cycle. The majority of today's vehicles are designed for personal property. For this reason, it is aimed to meet a number of different requirements today and in the future, which cause the increase of five or more passengers and large luggage capacity, alternative fuel and safety regulations, and similar important variables in new autonomous vehicle designs. In addition, it is observed that the current changes in the concept of individual mobility and vehicle ownership models, autonomous vehicles come to life in lighter or modular concept structures [17] [18] [19] [20]. The first versions of autonomous vehicles to go into mass production under competition have come to life in optimizing under existing technologies of over-engineered parts and components, often designed to cope with peak loads and performance demands caused by the user. This has allowed the design and development of smaller and lighter components that do not need to meet a wide range of extreme performance points in autonomous vehicle design.

Due to today's communication network speed, the increased usage and travel times of autonomous vehicles create a significant disadvantage on the life and maintenance requirements of the vehicle power transmission system. Depending on the needs for highly autonomous vehicle usage time (communication network services and charging structure), the characteristics, capacity and weight of the energy systems in the vehicle affect the reuse time (**Table 1**). In addition, comfort, entertainment and communication systems in autonomous vehicle technologies, human-machine interface systems and similar shared vehicle energy use, increasing digital technology parts are increasingly bringing the design of fuel and powertrains to the fore (**Table 1**). However, today the increasing availability of accurate real-time information on traffic and environmental infrastructure, public and private roads pricing and other conditions related to usage infrastructure has provided a blueprint for the implementation of advanced autonomous vehicles. The autonomous driving levels determined by the American Association of Automotive Engineers (SAE) are given below (**Table 1**).

Today, the autonomous capabilities of a vehicle can be at very different levels (**Table 1**). In autonomous vehicles, digital transmissions along with electronic drivetrains have begun to use geospatial data to inform shift points [21] [22] [23]. The system integration of such road and environmental infrastructure data with event data that causes travel speed-time changes such as traffic density or red lights provides a more efficient use of vehicle energy management. Therefore, while the integration or use of autonomous driving capabilities into our life model is a visible development, the design of these technologies under the future

Table 1. SAE levels of driving automation vehicle [14] [21].

<table>
<tr><th colspan="14">Autonomous Vehicle Regulation Level</th></tr>
<tr><td>SECURITY PROCESS</td><td colspan="12">DAS</td><td>SAFETLY PROCESS</td></tr>
<tr><td colspan="14">↓</td></tr>
<tr><td>SAE J3061</td><td colspan="12">SAE J3016</td><td>ISO 26362</td></tr>
<tr><td>↓</td><td></td><td colspan="6">DOT</td><td colspan="3">DDT-Failback</td><td colspan="2">ODD</td><td>↓</td></tr>
<tr><td rowspan="4"></td><td>LEVEL</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>DRIVER</td><td>USER</td><td>ADS</td><td>LIMITED</td><td>UNLIMITED</td><td rowspan="7"></td></tr>
<tr><td>0</td><td></td><td></td><td></td><td></td><td></td><td></td><td>🟥</td><td></td><td></td><td></td><td></td></tr>
<tr><td>1</td><td></td><td></td><td></td><td></td><td></td><td></td><td>🟥</td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td>🟨</td><td>🟨</td><td></td><td></td><td></td><td></td><td>🟥</td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">FEATURE DEFINITION</td><td>3</td><td>🟨</td><td>🟨</td><td>🟨</td><td>🟨</td><td>🟨</td><td>🟨</td><td></td><td>🟥</td><td></td><td>🟦</td><td></td></tr>
<tr><td>4</td><td>🟨</td><td>🟨</td><td>🟨</td><td>🟨</td><td>🟨</td><td>🟨</td><td></td><td></td><td>🟥</td><td>🟦</td><td></td></tr>
<tr><td rowspan="2">↓</td><td>5</td><td>🟨</td><td>🟨</td><td>🟨</td><td>🟨</td><td>🟨</td><td>🟨</td><td></td><td></td><td>🟥</td><td></td><td>🟦</td></tr>
<tr><td colspan="12"> </td><td>↓</td></tr>
<tr><td>Threat Analysis & Risk Assesments TARA</td><td>↔</td><td colspan="6">DAS TARA</td><td>↔</td><td colspan="3">DAS HARA</td><td>↔</td><td>Hazard Analysis & Risk Assement HARA</td></tr>
<tr><td colspan="14">↓</td></tr>
<tr><td colspan="2"></td><td colspan="6">Functional Security Concept</td><td>↔</td><td colspan="3">Functional Safety Concept</td><td colspan="2"></td></tr>
<tr><td colspan="14">↓</td></tr>
<tr><td colspan="2"></td><td colspan="6">Security Requirement</td><td></td><td colspan="3">Safety Requirement</td><td colspan="2"></td></tr>
<tr><td colspan="14">↓</td></tr>
<tr><td colspan="2"></td><td colspan="6">Security assessment</td><td></td><td colspan="3">Safety Assessment</td><td colspan="2"></td></tr>
<tr><td>🟨</td><td>Not Relevant</td><td></td><td colspan="2">🟦</td><td colspan="4">Only One is Relevant</td><td>🟥</td><td colspan="2">All are Relevant</td><td>⬛</td><td>High Relevant</td></tr>
</table>

foresight and the discovery of innovations stem from the process definition with a systematic approach.

The integration of components such as hardware, software and infrastructure that make up the functional structure of autonomous vehicle design is constantly evolving (Figure 1). As autonomous vehicle technology features are used more and more in newly developed vehicles, the approach to eliminating driver-related errors regresses, and accordingly, the need for lighter vehicles and lower power in the design emerges (Figure 1). Among these components, the headline driving automotive design is hardware [17] [18] [19] [20] [21].

In the very long term, new structures will emerge that have a lasting impact on the powertrain of these vehicles due to the reduced accident rates and the consequent reduction in vehicle weight from the bodywork as advanced autonomous vehicle technologies are incorporated into the majority of vehicles (Figure 1). One of the autonomous vehicle technologies in Figure 1 and Table 2, lane change assistant (LCA): this system is located on the left or right, front or rear of the vehicle. It monitors areas at a distance of 50 meters and warns the driver of a

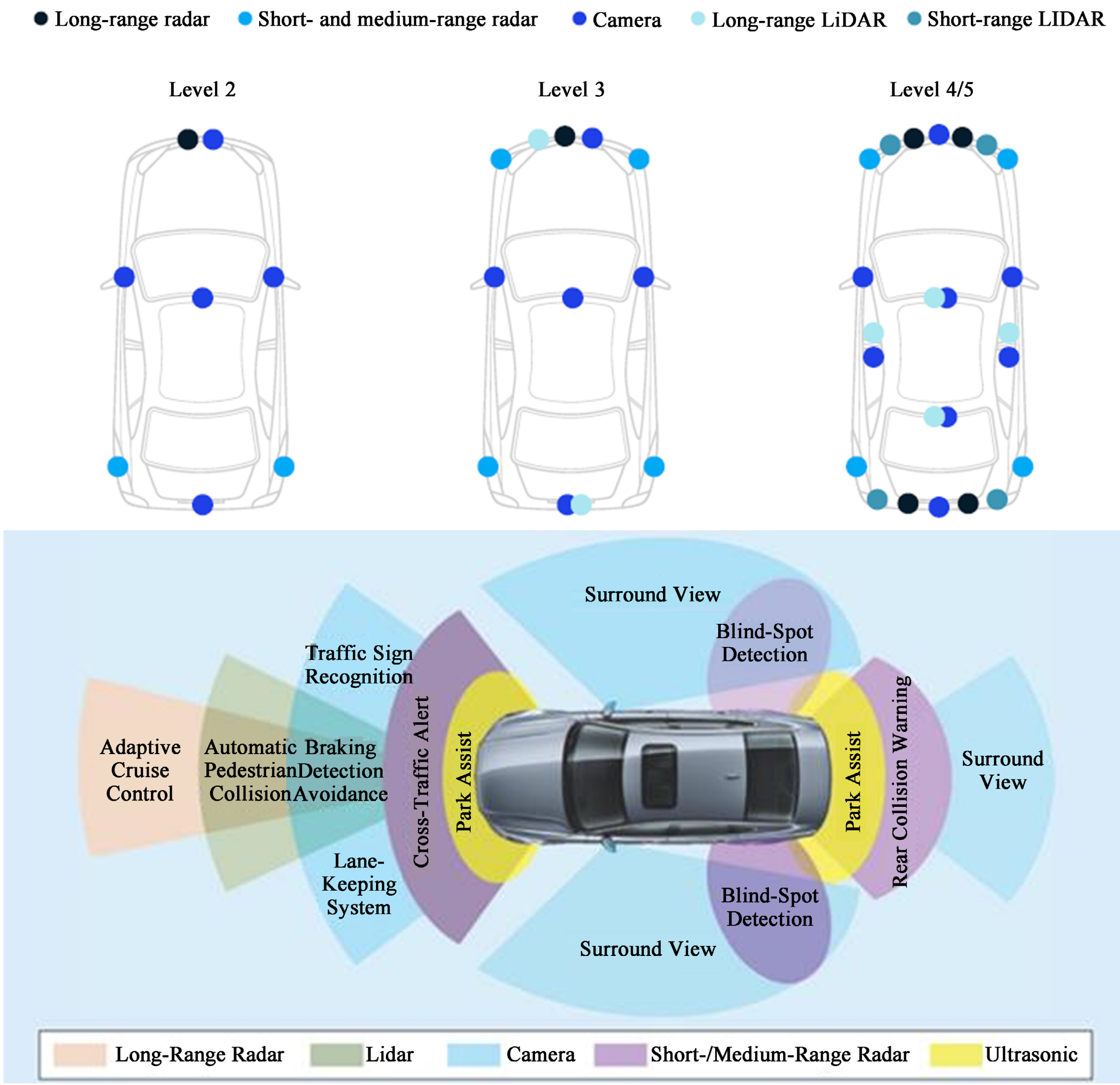


Figure 1. On-board equipment for autonomous driving [17].

possible dangerous situation with flashing warning signals in the exterior mirrors. Park distance control (PDC): the system supports the driver to Manuel in tight spaces, informing the distance to obstacles via the display, audio or optical signals. Lane Departure Warning (LDW): It warns the driver with seat or steering wheel vibration that the vehicle is about to unintentionally leave the lane in which it is traveling. Forward collision warning (FCW): the system uses a radar sensor to detect situations where the distance to the vehicle ahead is critical and helps reduce the vehicle's stopping distance [17] [18] [19] [20] [21]. Adaptive cruise control (ACC): uses a distance sensor and an adjusting lever for the driver around the steering wheel to measure distance and speed relative to vehicles ahead. Stop-and-go control (SACC): in addition to adaptive cruise control, it includes automatic distance control (0 - 250 km/h control range) and detects the vehicle ahead within system limits. Lane Keeping Assist (LKA): automatically at a certain speed (normally about 60 km/h), the system detects lane markings and takes corrective action to keep the vehicle positioned and not deviating from the lane. Park assist (PA): automatically guides the vehicle to parking spaces and supports the driver by automatically performing optimum steering movements to park back on the ideal line. In addition, it automatically performs the measurement of the parking space, the allocation of the starting position and the gas-brake steering movements (Table 2). The fully autonomous vehicle (level 5) must be able to make all the rides from point A to point B without any input from the passenger. The driver can always override or shut down the system. The CAN communication network on the vehicle and the data rates on this network are exemplified below (Table 2) [22] [23]. The sensors and technologies used in autonomous vehicles are developing functionally day by day (Table 2).

Autonomous vehicle technologies in Table 2 direct the vehicle by using the speed and distance of the vehicle, environmental conditions, and Lane, Lidar or Radar systems. The time elapsed during the instantaneous reception and transmission of

Table 2. Function-oriented CAN communication protocol in autonomous vehicles [14] [22] [23].

CAN BUS (Controller Area Network)											
Class	**Transfer Range**	**Autonomous Technologies**			**Data Rate**	**CAN Protocol**					
A-CAN	**10 Kbps**	A1	AHS	Auto Headlamp and Signal							
		A2	RD	Roll Down	Low Data Rate	OEM	RADAR		ACC ECU		CAN
		A3	GL	Gateway Lock							
		A4	KE	Keyless Entry		LIN					
B-CAN	**10-125 Kbps**	B1	BCU	Body Control Unit	↓						CAN
		B2	PAU	Park Assistant Unit			Distance setup				
		B3	IPC	Instrument Panel Cluster		J1850					
		B4	ECC	Electronic Climate Control							
		B5	SDU	Sensing and Diagnostic Unit		VAN					
		B6	CTU	Convergence Telematic Unit			Break lamp				
		B7	RRU	Radio Receiver Control Unit							
C-CAN	**125 Kbps – 1Mbps**	C1	SAU	Steering Angel Control Unit		Safe-by-Wire			PCM ECU		CAN
		C2	ECU	Engine Control Unit			Cruise control				
		C3	BCU2	Body Control Unit-2							
		C4	TCU	Transmission Control Unit							
		C5	BSCU	Brake System Control Unit			Electronic throttle				
		C6	YRU	Yaw Rate Control Unit							
		C7	ESC	Electronic Stability Control							
D-CAN	**5 Mbps**	D1	PAD	Park Area Distance		D2B optic	Wheel speed		DSC ECU		CAN
		D2	ADC	Automatic Distance Control			G Sensor				
		D3	FCW	Front Distance Control			Break Pressure				
		D4	LDW	Lane Departure Wide							
		D5	SV	Stereo Vision -Video		Most					
		D6	IC	Infrared Camera			Break Actuator				
		D7	LD	Lidar (Laser Scan)							
		D8	RD	Radar (High & Low Range)							
		D9	US	Ultrasounds		IEEE 1394	Steering angle sensor		BCM ECU METER		
		D10	WE	Wheel Encoder							
		D11	GPS	Global Position Navigasyon							
		D12	LKA	Lane Key Appoint		Flex Ray	Display				
		D13	LG	Lane Guidance	Peak Data Rate						

information is the key point in determining the distance, in order to determine the vehicle speed, the frequency shift in the reflected beam is calculated with the Doppler Effect (Table 2). Accordingly, the digital brake and throttle control the vehicle's road speed and its distance from other dynamic or stationary objects. This system is mostly developed for use in homogeneous flow highway. Communication and communication system in autonomous vehicles, sensors connected to the CAN system receive sensor signals such as Radar, Lidar, Lane, etc., and send commands to actuate digital actuators via control units (Table 2). This system uses control area network (CAN) for communication between vehicle components (Table 2).

The CAN system consists of a standard network structure using 2 basic cables to receive and transmit data from the ACC system (Table 2 & Figure 2). Therefore, each node coming to the CAN system transmits 0 to 8 bytes of messages in the message header. The main role of the message header in question is to decide the priority of the message. Therefore, the message with the highest priority is transmitted first. When it finds a free space to transmit the secondary message, it tries to send its message again. On the other hand, among the systems connected to the CAN line, the engine control module (ECU): is to adjust the travel speed by controlling the digital throttle of the vehicle power engine. When the autonomous vehicle engine control ECU receives information from the ACC module, it controls the vehicle speed. Brake control module (BAC), which directs the counterforce of this system: Activates the digital brake system when needed by the ACC module. Sensors (Brake Pedal Sensor, Accelerator Pedal Sensor, Radar Sensor, Four Wheel Sensor, etc.) and actuators in autonomous vehicles (Brake Actuator (BA), Throttle Actuator (TA), etc.) are increasing with newly added functions. The main function of the brake actuator (BAC) is to determine vehicle speed or reduce vehicle speed by signaling the vehicle throttle actuator (TAC). The main function of the digital throttle actuator (TAC) is to control the

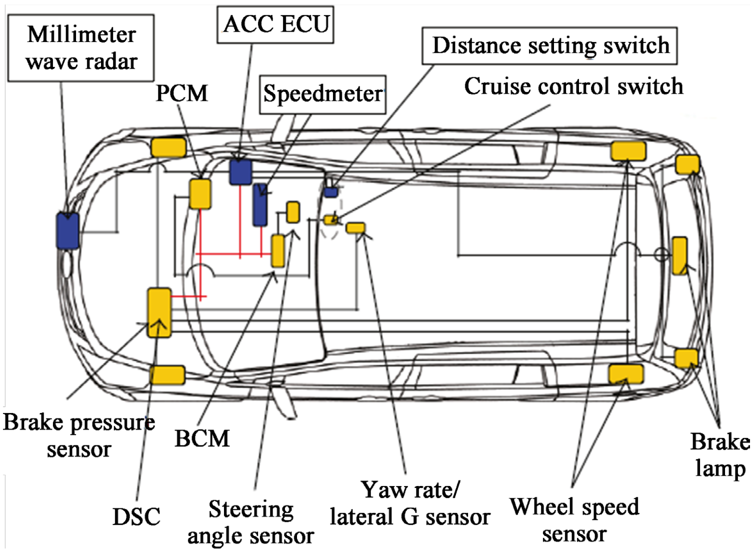


Figure 2. Positioning of autonomous vehicle technology components [25] [26].

throttle valve according to the need of the ACC system. The Radar system in **Figure 2** consists of multiple Radar sensors mounted on the front, rear and sides of the vehicle to detect the presence of other external objects [22] [23] [24]. The system in question has the use of three overlapping radar beams at a frequency of 76 - 77 kHz. Such a system can detect vehicles and objects up to 120 meters away. In addition, the most basic advantage of the system is that it can work efficiently even in bad weather. On the other hand, the Lidar system is a laser-based system (**Figure 2**). Therefore, the lidar system uses a narrower laser beam than a drop of water. The response time of the driver in the lidar system: It is the time interval for the instant response of the driver in an undesired situation [24] [25] [26]. In other words, the safe distance in the Lidar system is the minimum distance between the vehicle in front and is used at this distance so that the driver can take the necessary action by applying the brakes in an emergency (**Figure 2**).

The main function of autonomous vehicle technologies in **Figure 2** is to travel at a safe speed and time on the route determined by the driver. Maintaining the speed in suitable road conditions or maintaining an appropriate distance between two vehicles is realized by the simultaneous operation of four control processes [26] [27]. Lane keeping system (LKAS) is used as an active safety system and aims to reduce unwanted lane departures [27] [28]. The difficulty of using this function in autonomous vehicles lies in identifying dangerous situations and designing appropriate warning or response strategies. The system is designed to stop unnoticed by the driver and only activates when the driver misdirects the steering control. Also, unlike systems that emit an audible warning, the warning type is haptic feedback via the steering wheel. Said torque is designed to transmit to the driver the appropriate steering angle needed to return in the lane. In addition, the LKSA system uses an electric power assisted steering system (EPAS) actuator to generate the required offset torque at the steering column, while a CCD camera is used to detect the current lane position. Since EPAS is primarily used for power assisted steering, it provides an assist torque determined by the assist curve and current driving conditions. Therefore, every system used for safety in autonomous vehicles is designed to have a good interface between human and machine. On the other hand, the ACC system is an extension of the traditional cruise control system. In this system, the buttons connected to the digital steering wheel are positioned for the driver to make the necessary interventions. Although the system in question is an extension of the traditional cruise control system, it includes all steering and control buttons already included in the system. In addition, the interface design and positioning the instrument panel that the driver can perceive in short times or in variable conditions helps the driver to take the appropriate action in a short time. Directions that should be found in the said steering wheel and references; ACC, ASC, DSC, SACC, ECU, and range control button are located on the instrument screen together with the millimeter wave radar. In addition, when the routing group in the system is examined; Throttle control (TAC), brake control (BAC) and throttle actuator (TA) and brake actuator (BA) are integrated into the display system. More importantly, the driver displays and steering system components consist of parts with multiple vehicle steering functions arranged to perform their own functions. Therefore, the communication method between modules with different functions defines a set of communication link structures known as the controller area CAN-Network (**Table 2**).

Signals from sensors such as cameras, laser scanners and odometer units, which are the design elements of the driving support system commonly used in autonomous vehicle technologies, are processed and combined in a data fusion module. The main task of the elements that make up the vehicle design in question is to ensure that the relevant objects and lanes in a certain area around the journey are defined as the input of the road planning module. The main task of automatic steering in autonomous vehicle design is the automatic steering control of the vehicle or the automatic implementation of the vehicle trajectory, which must be done by the driver, depending on the digital sensing systems.

2.2. Automotive Concept Design Stages

While autonomous vehicles promise a more efficient journey compared to the driving values of today's vehicles, their interaction with traffic, infrastructure and environmental telematics facilitates their use in different and variable conditions. In principle, these options are already available on vehicles with partial or semi-autonomous driving functions, but high changes in ride comfort are foreseen during the next step of fully autonomous driving.

Driving today's vehicles requires a basic body and running chassis, within standard requirements. The basic function of the said vehicle chassis is to fulfil the functions of the autonomous vehicle, and the comfort of travel during autonomous driving is also an important automotive design input. Therefore, design alternatives are being developed that can make activities such as reading, working, eating or sleeping convenient options for travel for the majority of 1 - 5 people involved in autonomous vehicle use [29]. Autonomous vehicle design or travel in near-future scenarios may make this possible. In the new vehicle user group in question, there is a more advanced life model expectation and change. While there is a need for a driver who has driving orientation in the vehicle today, with autonomous driving, a new use case is now creating where any of the passengers in the vehicle can be the driver. There is also the possibility that this person is a disabled person who does not have a license to drive, or a teenager or child who is not allowed to drive because of their age. Therefore, in autonomous vehicle design, not only the adaptation of new technologies, but also the integration of different functions related to the freedom brought by autonomy drives automotive design concepts. Attached are the interdisciplinary flow steps of the current automotive design process in Paker's research (**Table 3**) [3] [13].

Autonomous vehicle design is a fundamental part of a complex and innovation-oriented product development structure with lean processes that require

Table 3. Automotive concept design process [3] [13].

Automotive Design Process																									
COD	**Automotive Concept Design Stages**	**Project Time Line (Phases/ Month)**																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
D01	2D Idea, Doodle	▨	▨	▨	▨	▨	▨																		
D02	2D New Vehicles Sketch			▨	▨	▨	▨	▨	▨																
D03	2D Technical Drawing						▨	▨	▨	▨															
D04	2D Presentation - Approval								▨	▨	▨	▨	▨												
D05	3D Clay Model			▨	▨	▨	▨	▨	▨	▨	▨														
D06	3D Digital Scanning - CNC				▨	▨	▨	▨	▨	▨	▨	▨	▨	▨											
D07	3D CAD Vehicle model					▨	▨	▨	▨	▨	▨	▨	▨												
D08	*3D Virtual Prototype*						▨	▨	▨	▨	▨	▨	▨	▨	▨										
D09	3D User Experian	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨													
D10	3D Interface Control			▨	▨	▨	▨	▨	▨	▨	▨														
D11	Interior&Exterior IoT system	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨													
D12	3D Rapid Prototype									▨	▨	▨	▨	▨	▨										
D13	*3D Interior/ Exterior Trim*										▨	▨	▨	▨	▨	▨	▨								
D14	*3D Interior/ Exterior Mock-Up*														▨	▨	▨	▨							
D15	3D Virtual Assembly															▨	▨	▨	▨	▨					
D16	3D A- Class CAD Surface																	▨	▨	▨	▨	▨	▨		
D17	3D CAD Vehicle Data Transfer																				▨	▨	▨	▨	▨

the use of many different new engineering disciplines (**Table 3**). In addition, the automotive design stages, with the starting position where the lean product development process targets are determined, is the most important part where the innovation takes form and the project targets become physical and differentiate (**Table 3**). The basic expectation in autonomous vehicle design is modelling of living spaces that can perform various indoor and outdoor tasks with high precision in different and variable road conditions. Therefore, the sensors positioned on the autonomous vehicle should systematically define the traffic and traffic infrastructure, the environment, be able to make decisions under the incoming instant information and guide these decisions reactively through control systems. While the focus of autonomous vehicle design or system boundaries involves dynamic interaction with the traffic environment and other road stakeholders, the scope is broadened by the inclusion of new technologies. Therefore, it is expected from the automotive design stages that the autonomy of the vehicles will also reveal possible new usage and comfort structures, resulting in a high-performance increase in the daily life standard for both the vehicle and the passengers. However, in the existing and digital equipment adaptations of autonomous vehicles, it is expected from the design team that the simultaneous electronically controlled maneuver's will be dominated by the location and use of digital systems that will take place in the current traffic and new flow. These opportunities include driving in particularly narrow driving lanes or convoy driving within relatively small distances between vehicles [29]. It is advocated that by 2030, such autonomous vehicles will become sufficiently reliable and will begin to replace human-driven vehicles [30]. Automotive design stages have remarkable effects on the vehicle interior and exterior structure, which includes various uses, or on the interface created by human-machine interaction. In the autonomous vehicle driving task, which means instantaneous changes in connection with traffic and its artificial environment and instantaneous response to them, determining legal responsibility apart from design responsibility may have important consequences in the transition to the new life model. Although this is not a difficult issue to achieve in autonomous vehicle body structure or digital motor chassis applications, it can reveal urgent needs for passengers. As is the case today, the determination of the nature for autonomous vehicles, and especially by simulating the interior design of the vehicle, the travel time gains will create new conditions of competition among automotive companies. Autonomous driving technology reveals quite a variety of positive results on the customer and market structure today. On the one hand, modules that transform into living spaces such as living rooms, dining rooms, offices or bedrooms with dynamic use, on the other hand, the seat structure with variable functions allows autonomous vehicle designs that support high comfort features. On the other hand, it is one of the results of the same approach that the vehicles with the benefit of optimized costs are included in the minimalized body structure, which includes standard technologies for autonomous transportation services, and the designs for urban and extra-urban.

It is foreseen today that the vehicles designed for the specified use cases will cause significant changes in the urban and extra-urban service sector, resulting in the emergence of many by-products and secondary products [31]. Automotive design process, preliminary definitions (after-sales failure rates, manufacturing and workmanship difficulties, regional and global supply source etc.) that include information and statistics about the vehicle in current production, which creates high costs for the company, and customer's innovation expectations (user experience researches) starts with determining the main project objectives. In the light of this information, new automotive design concepts, which are in the maturation process with user experience studies, become suggestions under visual representations. After the aforementioned "validity and newness" of the proposal is checked, feasibility studies, preliminary design and detailed design are carried out respectively, and the emergence and development of a new vehicle product visible on the model continues (**Table 3**). Therefore, a good design meets the customer's requests and expectations, while achieving this at the lowest cost, and at the same time, the need for frequent corrections of the new product produced as a result of the design is prevented. Transferring new autonomous vehicle technologies to the automotive design department or defining them as a result in phase-transition approval with the interdisciplinary stakeholders of the preliminary project information. In such a case, automotive design expertise acts in the direction of efficiently positioning parts containing autonomous vehicle technologies, ensuring that these parts work in variable conditions, and solving problems in vehicle and environment integration. Therefore, in the automotive design phase, where innovations are realized, the range of motion will be limited. Another approach is that the discipline of automotive concept design may reveal negative variables within the scope of making a difference, instead of the functional area or positioning required by the autonomous vehicle technology parts of which it has only general knowledge. In addition, the study preferred a qualitative research method in order to observe and question the variables in question in the field.

3. Research Method

The research includes one-on-one interviews on current autonomous vehicle design, and the analysis and synthesis of the AHP survey application. The publication, which includes the sharing of the first stage of the study, includes one-on-one interview analysis. The research was carried out in 3 local, 3 global, 6 automotive industry companies with different organizational structures operating in the same location, partner in new autonomous vehicle projects with the process managers who orbits in autonomous vehicle design (10 from each participating company, a total of 60 company managers) is completed with the identification and comparison of values.

The time and business-oriented flow created by autonomous vehicle technologies, which are newly included in the automotive concept design stage, is the key concept of competitive development in all sectors, not only in the automotive industry, in the functioning of the new product development process. Therefore, when the variables in the subject-specific application area are examined: In the studies of Eppinger (2012), Ulrich (2011), Ullah (2016), the dominant effects of the automotive design stages in the initial phase of the new product development process were investigated in the whole flow-oriented process [5] [32] [33]. In his study, Ulrich (2011) made comparisons in different sectors on the automotive design variables and durations involved in the phase transitions while defining the new product development phases sequentially [5]. Ulrich (2011) and Eppinger (2012) reported in their studies: Until the 1990's, the product realization function focused on the manufacturing stages, and after the 2000's, under competition, structures focused on design and simplification [5] [32] [33]. In his research, Ullah (2016), in addition to Ulrich's investigations in the new product development process until 2015, listed the variables that affect the subject, and examined the product designs and achievements in different industries on a company basis and comparatively [5] [32]. In studies included in the literature research; the number of new product design and development employees and time, the number of new product parts, new product life cycle, development project cost or results and similar factors constitute the comparable structure variables of the basic process. When the structure and gains affected by the new product design process are viewed on a sectoral basis, they constitute approaches worth studying [34]. Therefore, the fact that the research is carried out in a structure that results in the use of different design steps and techniques in different companies in the same sector will lead to result-oriented principles in practice. In addition, in his research, Ulrich stated that the first period sequential design step operation in the 1970-80's, in the second period, 1980-90's, took on the design verification step in parallel with the formation of the business stages, and in the last period 2000-10, the joint design process stakeholders, he stated that he had a simultaneous flow under his job descriptions, and finally, in the 2010-20's, the design process started to become simpler with all its stakeholders and duties [5] [34].

4. Concept Design Stages Comparison on LC/GC Automotive Companies

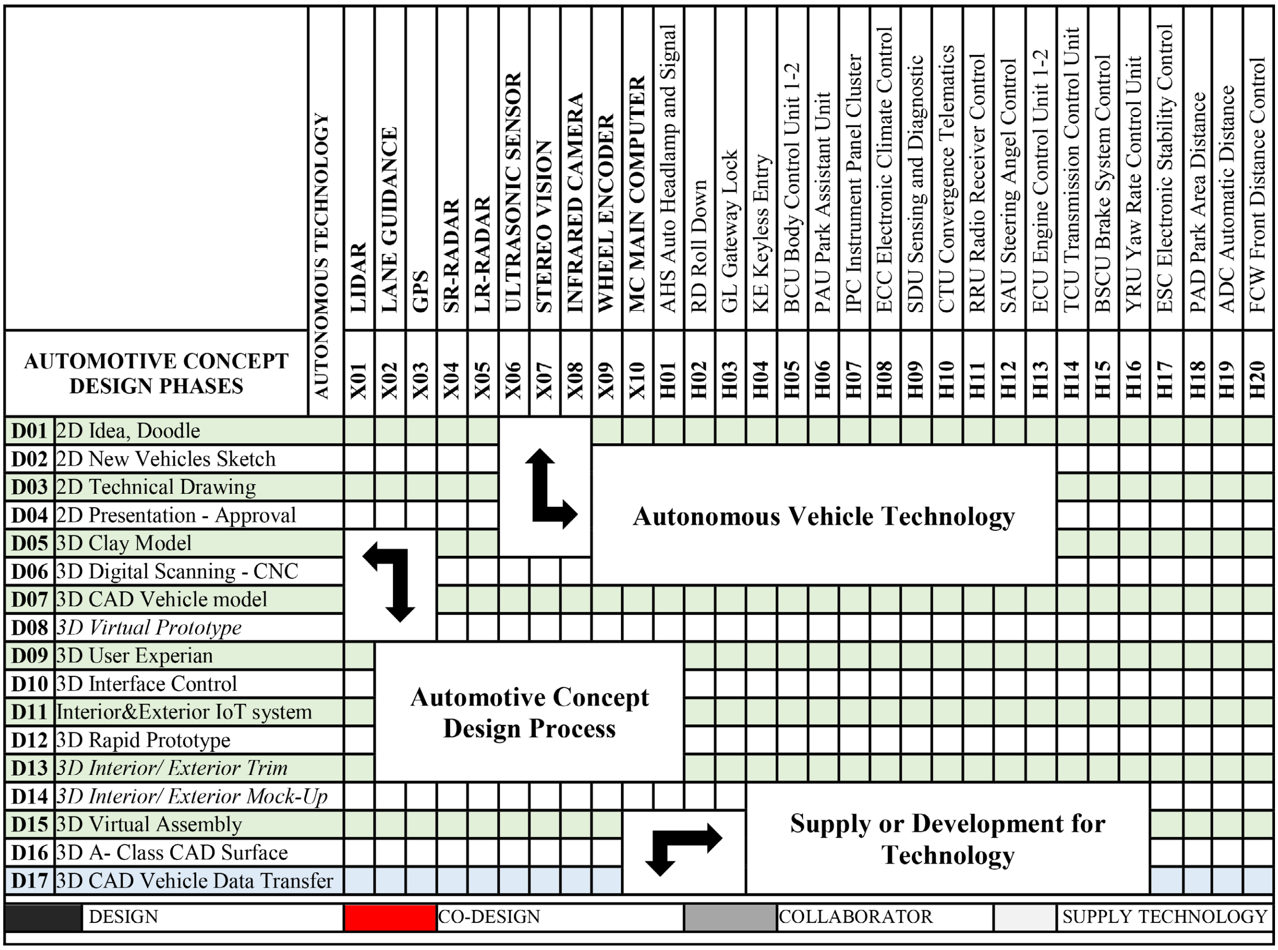
Automotive concept design stages, including autonomous vehicle technologies, were determined in one-on-one interviews with automotive industry companies in the field researches within the scope of the study. Although the mentioned stages show qualitative and quantitative differences in six automotive industry companies, no difference was observed in the definitions and applications of autonomous vehicle technologies. Therefore, when the differences and similarities in the automotive design stages were examined at the functional level, it was determined that the same business group was worked under different headings. However, the large number of automotive design stages realized in global automotive industry companies compared to local companies led to the use of matrix tables, which constitute the comparison structure of the research (**Table 4**). In the appendix, the stages of global automotive companies with high levels of work and progress, together with current autonomous vehicle technologies, are given (**Table 4**). In the comparison, which is part of the approach created on the same axis, missing or different flow steps are also indicated in the tabulation content (**Table 4**).

In the horizontal part of the matrix table in **Table 4**, the automotive design stages identified in the fieldwork are located, while the newly introduced autonomous vehicle technologies are located in the vertical part (**Table 4**).

Another important point determined in the field research of the study is the finding that the autonomous vehicle technologies of the global automotive industry companies, either developed by themselves or RD (research and development) companies established in a subsidiary or partnership structure take this task and responsibility. Therefore, the cost, time and labor force or market that local automotive industry companies lose while adapting autonomous vehicle technologies they supply through external supply channels result in great losses in the competitive environment. While this situation creates positive values in global companies, which constitute the opposite part of the same approach, the increase in the number of software, hardware, workforce and employees reveals large investments.

The approach in the work axis, the entry level of new autonomous vehicle technologies today, the integration of next generation autonomous technologies

Table 4. Autonomous vehicle technologies on automotive concept design process.



AUTOMOTIVE CONCEPT DESIGN PHASES

AUTONOMOUS TECHNOLOGY

X01	LIDAR
X02	LANE GUIDANCE
X03	GPS
X04	SR-RADAR
X05	LR-RADAR
X06	ULTRASONIC SENSOR
X07	STEREO VISION
X08	INFRARED CAMERA
X09	WHEEL ENCODER
X10	MC MAIN COMPUTER
H01	AHS Auto Headlamp and Signal
H02	RD Roll Down
H03	GL Gateway Lock
H04	KE Keyless Entry
H05	BCU Body Control Unit 1-2
H06	PAU Park Assistant Unit
H07	IPC Instrument Panel Cluster
H08	ECC Electronic Climate Control
H09	SDU Sensing and Diagnostic
H10	CTU Convergence Telematics
H11	RRU Radio Receiver Control
H12	SAU Steering Angel Control
H13	ECU Engine Control Unit 1-2
H14	TCU Transmission Control Unit
H15	BSCU Brake System Control
H16	YRU Yaw Rate Control Unit
H17	ESC Electronic Stability Control
H18	PAD Park Area Distance
H19	ADC Automatic Distance
H20	FCW Front Distance Control

D01	2D Idea, Doodle
D02	2D New Vehicles Sketch
D03	2D Technical Drawing
D04	2D Presentation - Approval
D05	3D Clay Model
D06	3D Digital Scanning - CNC
D07	3D CAD Vehicle model
D08	*3D Virtual Prototype*
D09	3D User Experian
D10	3D Interface Control
D11	Interior&Exterior IoT system
D12	3D Rapid Prototype
D13	*3D Interior/ Exterior Trim*
D14	*3D Interior/ Exterior Mock-Up*
D15	3D Virtual Assembly
D16	3D A- Class CAD Surface
D17	3D CAD Vehicle Data Transfer

Autonomous Vehicle Technology

Automotive Concept Design Process

Supply or Development for Technology

■ DESIGN 🟥 CO-DESIGN ▨ COLLABORATOR ☐ SUPPLY TECHNOLOGY

with the traffic infrastructure and environment have given birth to today's laboratory environment testing paths. Global automotive industry companies, which are involved in the development of these autonomous vehicle technologies, are both suppliers and partnerships of local automotive companies in the future. Therefore, apart from the acquisition of autonomous vehicle technologies, the competitiveness of local companies also reveals the stages and results of original automotive design.

4.1. Concept Design Stages on LC Automotive Companies

According to the results of one-to-one interviews and joint analysis with the design and development managers of local automotive industry companies, it was determined that the automotive concept design stages consisted of 6 to 8 steps (Table 5). The first two administrative managers of the LC1 automotive manufacturing industry stated that the increase in the concept design stages led to an increase in the project processes and that they were working to reduce this flow. The other 8 company executives think that the LC1 automotive concept design stages, new autonomous technologies on the vehicle, the form studies of the whole vehicle will make a difference compared to the competitors, with a longer

Table 5. LC Automotive concept design process on autonomous technology.

LC **AUTOMOTIVE CONCEPT DESIGN PHASES**	**LC** AUTONOMOUS TECHNOLOGY	**X01** **LIDAR**	**X02** **LANE GUIDANCE**	**X03** **GPS**	**X04** **SR-RADAR**	**X05** **LR-RADAR**	**X06** **ULTRASONIC SENSOR**	**X07** **STEREO VISION**	**X08** **INFRARED CAMERA**	**X09** **WHEEL ENCODER**	**X10** **MC MAIN COMPUTER**	**H01** AHS Auto Headlamp and Signal	**H02** RD Roll Down	**H03** GL Gateway Lock	**H04** KE Keyless Entry	**H05** BCU Body Control Unit 1-2	**H06** PAU Park Assistant Unit	**H07** IPC Instrument Panel Cluster	**H08** ECC Electronic Climate Control	**H09** SDU Sensing and Diagnostic	**H10** CTU Convergence Telematics	**H11** RRU Radio Receiver Control	**H12** SAU Steering Angel Control	**H13** ECU Engine Control Unit 1-2	**H14** TCU Transmission Control Unit	**H15** BSCU Brake System Control	**H16** YRU Yaw Rate Control Unit	**H17** ESC Electronic Stability Control	**H18** PAD Park Area Distance	**H19** ADC Automatic Distance	**H20** FCW Front Distance Control
		🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
D02	2D New Vehicles Sketch	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
D03	2D Technical Drawing	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	▒	▒	▒	▒	▒	▒	▒	▒	▒
D07	3D CAD Vehicle model	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
D10	3D Interface Control	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
D12	3D Rapid Prototype	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒									
D13	*3D Interior/ Exterior Trim*	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
D14	*3D Functional Prototip-Mockup*	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
D17	3D CAD Vehicle Data Transfer	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥

⬛	DESIGN	🟥	CO-DESIGN	▒	COLLABORATOR	🟦	SUPPLY TECHNOLOGY

time and more discipline. Therefore, 8 company executives shared that traditional automotive design processes are not sufficient in autonomous vehicle technology adaptations and that they are planning new stages in addition to the existing ones. LC1-LC2 and LC3 company executives stated that the autonomous vehicle projects included in the product ranges they manufacture and design use technology within the framework of project-based agreements they have purchased, together with joint or outsourced parts and applications with local technology companies. Attached is the matrix table of new autonomous vehicle technologies along with the concept design steps of local automotive companies (Table 5).

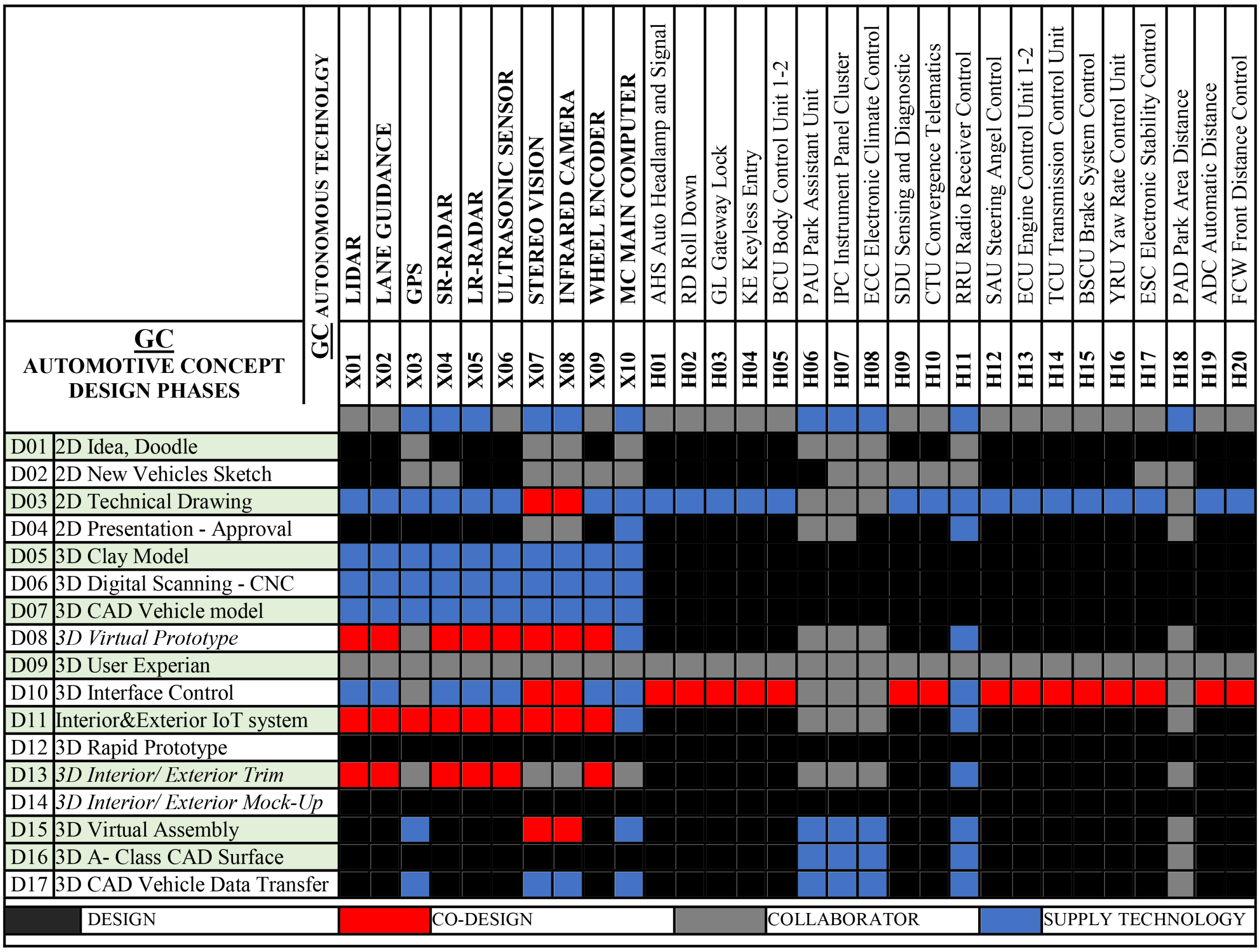
As explained in Table 5, the process of autonomous vehicle technologies included in the local automotive concept design stages; The application of the ready-made technology piece by the company designers, the implementation of the design application of the technology piece by the developer company, the joint development application of the technology piece and the full application of the technology piece by the supplier (Table 5). Therefore, the development and implementation of autonomous vehicle technologies in the original automotive concept design stages of the company, instead of supplier control, is an important approach to make a difference in the market or to gain competition. The application of the parts and systems that make up the basic autonomous vehicle technologies (Lidar, Lane, GPS, Radar, Ultrasonic Sensor, Stereo Vision, Infrared Camera, Wheel Encoder, Main Computer) to the automotive design stages under their physical needs and usage requirements, not only the placements on the 3D model, it also provides hardware and software support for the part

(**Table 5**). In addition, local automotive manufacturing industry companies that perform the basic positioning of new autonomous vehicle technology parts are the implementers of the supplier companies in the software operation of these parts. Additional costs are incurred for the development of new versions of these parts or the use of additional functions.

4.2. Concept Design Stages on GC Automotive Companies

As in the first group one-on-one interviews, according to the results of one-on-one interviews and joint analysis with the design and development managers of global automotive industry companies (GC1-GC2-GC3), it has been determined that the automotive concept design stages are common in 16 and 18 steps (**Table 6**). GC1 and GC2 company executives; The participants, who are aware that the most important value creation of global automotive companies in competition is through the ability to develop and design new products, stated that they take care to keep their automotive concept design processes up-to-date. Therefore, the concept design stages of global automotive industry companies have been designed with higher staff, multi-step, up-to-date software and hardware compared

Table 6. GC Automotive concept design process on autonomous technology.



GC AUTOMOTIVE CONCEPT DESIGN PHASES	GC AUTONOMOUS TECHNOLGY	LIDAR	LANE GUIDANCE	GPS	SR-RADAR	LR-RADAR	ULTRASONIC SENSOR	STEREO VISION	INFRARED CAMERA	WHEEL ENCODER	MC MAIN COMPUTER	AHS Auto Headlamp and Signal	RD Roll Down	GL Gateway Lock	KE Keyless Entry	BCU Body Control Unit 1-2	PAU Park Assistant Unit	IPC Instrument Panel Cluster	ECC Electronic Climate Control	SDU Sensing and Diagnostic	CTU Convergence Telematics	RRU Radio Receiver Control	SAU Steering Angel Control	ECU Engine Control Unit 1-2	TCU Transmission Control Unit	BSCU Brake System Control	YRU Yaw Rate Control Unit	ESC Electronic Stability Control	PAD Park Area Distance	ADC Automatic Distance	FCW Front Distance Control
		X01	X02	X03	X04	X05	X06	X07	X08	X09	X10	H01	H02	H03	H04	H05	H06	H07	H08	H09	H10	H11	H12	H13	H14	H15	H16	H17	H18	H19	H20
		▨	▨	🟦	🟦	🟦	▨	🟦	🟦	▨	🟦	▨	▨	▨	▨	▨	🟦	🟦	🟦	▨	▨	🟦	▨	▨	▨	▨	▨	▨	🟦	▨	▨
D01	2D Idea, Doodle	⬛	⬛	▨	⬛	⬛	⬛	▨	▨	⬛	▨	⬛	⬛	⬛	⬛	⬛	▨	▨	▨	⬛	⬛	▨	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛
D02	2D New Vehicles Sketch	⬛	⬛	▨	▨	⬛	⬛	▨	▨	▨	▨	⬛	⬛	⬛	⬛	⬛	⬛	▨	▨	▨	▨	▨	⬛	⬛	⬛	⬛	⬛	▨	▨	⬛	⬛
D03	2D Technical Drawing	🟦	🟦	🟦	🟦	🟦	🟦	🟥	🟥	🟦	🟦	🟦	🟦	🟦	🟦	🟦	▨	▨	▨	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	▨	🟦	🟦
D04	2D Presentation - Approval	⬛	⬛	⬛	⬛	⬛	⬛	▨	▨	⬛	🟦	⬛	⬛	⬛	⬛	⬛	▨	▨	⬛	⬛	⬛	🟦	⬛	⬛	⬛	⬛	⬛	⬛	▨	⬛	⬛
D05	3D Clay Model	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛
D06	3D Digital Scanning - CNC	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛
D07	3D CAD Vehicle model	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛
D08	*3D Virtual Prototype*	🟥	🟥	▨	🟥	🟥	🟥	🟥	🟥	🟥	🟦	⬛	⬛	⬛	⬛	⬛	▨	▨	▨	⬛	⬛	🟦	⬛	⬛	⬛	⬛	⬛	⬛	▨	⬛	⬛
D09	3D User Experian	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
D10	3D Interface Control	🟦	🟦	▨	🟦	🟦	🟦	🟥	🟥	🟦	🟦	🟥	🟥	🟥	🟥	🟥	▨	▨	▨	🟥	🟥	🟦	🟥	🟥	🟥	🟥	🟥	🟥	▨	🟥	🟥
D11	Interior&Exterior IoT system	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟦	⬛	⬛	⬛	⬛	⬛	▨	▨	▨	⬛	⬛	🟦	⬛	⬛	⬛	⬛	⬛	⬛	▨	⬛	⬛
D12	3D Rapid Prototype	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛
D13	*3D Interior/ Exterior Trim*	🟥	🟥	▨	🟥	🟥	🟥	▨	▨	🟥	▨	⬛	⬛	⬛	⬛	⬛	▨	▨	▨	⬛	⬛	🟦	⬛	⬛	⬛	⬛	⬛	⬛	▨	⬛	⬛
D14	*3D Interior/ Exterior Mock-Up*	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛
D15	3D Virtual Assembly	⬛	⬛	🟦	⬛	⬛	⬛	🟥	🟥	⬛	🟦	⬛	⬛	⬛	⬛	⬛	🟦	🟦	🟦	⬛	⬛	🟦	⬛	⬛	⬛	⬛	⬛	⬛	▨	⬛	⬛
D16	3D A- Class CAD Surface	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	🟦	🟦	🟦	⬛	⬛	🟦	⬛	⬛	⬛	⬛	⬛	⬛	▨	⬛	⬛
D17	3D CAD Vehicle Data Transfer	⬛	⬛	🟦	⬛	⬛	⬛	🟦	🟦	⬛	🟦	⬛	⬛	⬛	⬛	⬛	🟦	🟦	🟦	⬛	⬛	🟦	⬛	⬛	⬛	⬛	⬛	⬛	▨	⬛	⬛

⬛ DESIGN 🟥 CO-DESIGN ▨ COLLABORATOR 🟦 SUPPLY TECHNOLOGY to local companies, and lean principles in resource management. Rapid prototyping and clay model stages in 3 different techniques according to local companies, which constitute the other part of the comparison, provide significant support to original value creation in concept design. On the other hand, in certain steps of the concept design stages, planned feedback or approval modifications seem to dominate the holistic approach. Attached is the matrix table of new autonomous vehicle technologies along with the concept design steps of global automotive companies (Table 6).

As stated in Table 6, since it is the first section where new autonomous vehicle technologies are added to the vehicle with their physical requirements, automotive concept design studies take place in half the time of the new product development process. Having a full share in the design and development of new autonomous vehicle technologies, global automotive companies also provide critical hardware and software support in the new vehicle project adaptation of these technologies. Therefore, global automotive industry companies are both developers and suppliers of new autonomous vehicle technologies included in the automotive concept design stages (Table 6). On the other hand, since GPS, Radar, Camera, Main Vehicle Computer technologies, which are included in the automotive concept design stages, are realized entirely through the external supply chain, it has been observed in the field that additional working groups have been established on the adaptation of other autonomous vehicle technologies (Table 6). Although this situation creates periodic modifications in the automotive concept design stages, the high communication of the collaborative work teams in the solution and development of the problems arising in new technology applications prevents time and work losses.

5. Discussion and Comparative Future

Today, the development and production of autonomous vehicle technologies, which are included in the near future plans, are realized through global brand partnerships or brand acquisitions. Under these brand marriages, automotive industry manufacturing companies switch to RD (research and development) and PD (product development) center's that include both high technology and critical parts consolidation as well as mass production of these, as well as high resource investment and use. On the other hand, it is today's prediction that the said investments will monopolize the automotive industry in the future and make the local automotive manufacturing industry dependent on new technologies. When the local or global automotive manufacturing industry, which takes place within the boundaries of the research, is examined in detail, apart from the main body parts that come out of the automotive concept design stages, make a difference with the competitors, and make up a small part of the vehicle, most of them consist of parts supplied and assembled by the supply chain. Therefore, local or global automotive manufacturing industry companies perform full-time assembly with the supply chain, while on the other hand, they realize the main body structures that make a brand-specific difference with the automotive concept design stages.

Innovations in autonomous vehicle technologies, which support the new life model, where great changes are experienced in the communication and transportation of individuals today, will show changes in their development and design in the near future. This approach, apart from the acquisition of autonomous vehicle technologies, requires local companies to invest in new technologies in order to increase their competitiveness or position their brand value with unique automotive design. As observed from the field research, combining the concepts of vehicle and journey with home comfort or life in the near future has become the main topic of automotive concept design today. Therefore, home life and comfort, which has developed with the pandemic conditions, are being transferred to autonomous vehicles with the concept of mobility.

6. Conclusions

The research, which includes analysis and synthesis in the process comparison structure of global and local automotive manufacturing industry company structures under one-to-one interviews, focused on the competitive advantages and efficiency of the automotive concept design stages, where current autonomous vehicle technologies are first positioned in practice. Therefore, the fact that global automotive manufacturing industry companies are both developer partners and users of autonomous vehicle technologies provides the opportunity to make radical changes in the application problems and solutions of these technologies during the automotive concept design stages. In addition, the problems and solutions created by autonomous vehicle technologies in practice, or special developments for the designed vehicle structure, contribute greatly to the development and design stages of new products for global automotive industry companies, and also lead the way in innovations to be presented to the market. These autonomous vehicles and their new technologies, which are pioneers in the market, provide global spread on the basis of new product and component manufacturing, together with a high competitive advantage.

The fact that the local automotive manufacturing industry companies included in the research move into the position of developers instead of supplying autonomous vehicle technologies can create brand value with unique product-vehicle design, together with a cost advantage in competition. As mentioned above, automotive concept design stages are the first application discipline of autonomous vehicle technologies. The part dimensions of the technologies in question, their on-vehicle issues or usage volumes, connected system distances or display interfaces are determined during the automotive concept design stages. Therefore, the automotive concept design stages, which are included in lean product development, are the first step of the whole process. In addition, it creates value with its holistic approach to the whole process, where innovations are the first to materialize in a heavily competitive environment in the local or global automotive manufacturing industry.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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