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Autonomous Vehicle Design in Lean Product Development Processes for Value Stream Map

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Abstract

The global automotive industry is giving a difficult and common test in order to create advanced life models in the near future plans or scenarios that include current autonomous vehicle technologies. Therefore, the main purpose of the research is to comparatively evaluate the impact of autonomous vehicle technologies, which are newly included in the automotive manufacturing industry under sustainable competition, on lean product development processes, value acquisition and preservation, in different organizational structures in the approach. Although mergers or brand acquisitions in the global automotive industry create joint R & D (Research Development) or joint new P & D (Product Development) process structures for the development of autonomous vehicle technologies, heavy competition continues in the market. These new processes create different needs for the merger and partnership of the renewed traffic infrastructures under national and international regulations, and for the implementation of the new autonomous life model. Firm and brand marriages, mergers or acquisitions in today's automotive industry have ensured the high diffusion of lean product development processes under the stream of value creation or preservation carried out specific to the company under competition. Brand mergers in automotive industry companies struggling to survive under high competition create new work disciplines, professions, and engineering flow steps in lean product development processes. However, lean product development processes driven by technological innovation under simplification have resulted in the integration of parts and systems within the autonomous vehicle design structure, as well as creating new interdisciplinary value streams or different stakeholders. Therefore, the research revealed the significant effects of lean product development processes on the value stream in the automotive industry, on the mixed and lean product development process structure formed by new or existing vehicle systems (conventional vehicle) under the penetration of each existing and new discipline. This research compares the efficient operation steps of the process stakeholders in the autonomous vehicle design parts or systems containing innovation and new technology together with the value stream in the lean product development process, and the new process stakeholder's business-oriented global and local automotive industry companies. New autonomous vehicle technologies, together with their unique software, hardware and development analysis, have been involved in the lean product development process with their interdisciplinary studies or expertise. Therefore, the study firstly focused on the technologies in environmental use together with the new basic features of autonomous vehicles, and then examined in depth the new or existing disciplines and interdisciplinary basic structure that these innovations affect under the value stream in the lean product development process. In addition, micro-level results and recommendations were shared, shedding light on how autonomous vehicle levels will create changes in the new product development process.

Keywords

Automotive Industry, Lean Product Development, Design Management, Autonomous Vehicle Design, Value Stream Map

1. Introduction

Autonomous vehicles are defined as vehicles that reach the desired point from the point where they are, or that carry out the previously defined route or route with its own decision mechanism, without human intervention [1] [2]. Vehicles developed in the aforementioned lean product development processes reach diagnostic information through sensors of different types and features that they have environmental instantaneous data, and again perform reactive guidance according to instant situations and conditions. The vehicles in question reach diagnostic information through sensors of different types and features that they have environmental instantaneous data, and perform routing according to the instantaneous situation and conditions. In addition, it realizes the autonomy function by transmitting the necessary signals to the controllers to operate certain codes and correct actuators by the decision-making mechanism operating under defined instantaneous environmental information, state or conditions. Therefore, the reflex that autonomous vehicles give to instantaneous environmental effects; instantaneous dynamic speed flow direction, regional traffic flow rate, vehicle-driver-pedestrian safety, internal-external structure of the regional traffic order and journey flow continuity, lane discipline, following distance, partial (level 0, 1, 2, 3, 4, 5) or fully autonomous road continuity is revealed as the overlapping of autonomous road and vehicle levels, the penetration of similar variables. Many automotive industry companies have pilot projects (Level 4) that test autonomous vehicle technologies under certain conditions and definitions in practice [2] [3]. Alternative new problems and approaches created by autonomous vehicles in a dynamic environment: travel speed and efficiency, vehicle-driver-passenger-pedestrian safety and comfort, new travel needs (food-beverage, meeting, social integration, service, etc.), parking in a stable environment—space saving, parking, parking lot positioning, parking payment, parking lot charging—energy efficiency—time saving, focal points of vehicle projects designed under similar new life scenarios, project objectives, design of autonomous vehicles, reveals the variables belonging to different disciplines. However, the vehicle designs in the near-future scenarios within the said heterogeneous flow consist of different product features under different disciplines; theoretical and practical experiences of the concepts of internet of things, e-mobility, artificial intelligence; it directs humanity's transition to a new life model to common changes in global legislation and regulations. For modelling or good management of these conceptual developments under ethics and law, international law and similar scientific approaches; it is necessary to define, plan, comprehend, analyses and determine the principles of interdisciplinary product design phases.

Integrated and lean product design in the automotive industry, which the research main purpose at, or the gradual adaptation of autonomous vehicle technologies depending on the joint development processes of environmental conditions, today reveals important responsibilities with new concepts. Thus, different clusters of variables are surfacing in autonomous vehicle development; under the development of new concepts such as internet of things (IoT)—communication speed, E-Mobility/journey definition, artificial intelligence/decision making speed (CAV's), Big Data—data management, data speed and archiving; it has the potential to significantly change the way people live, work and travel [4]. The autonomous vehicle integration of these new concepts has revealed the speed and capacity and structural continuity of instant data exchange between the vehicle and the environmental-road conditions that make up the course of the vehicle in the lean product development processes of today's technologies. The value creation or preservation of autonomous vehicles under the streamlined development flow has provided various benefits until today, and has ensured the safe integration of various new disciplines into the lean product development process, after joint co-design studies of automotive industry companies with software and hardware companies. Autonomous vehicle development has been observed in the literature and field studies, including new disciplines with artificial intelligence (IoT) and data management (Big Data) application areas, with basic algorithms at the beginning level, to simplify product development processes. Autonomous vehicles or e-mobility; gives the opportunity to design a more productive, efficient, relaxing and functional living space during the travels of the passengers between two points, and in the lean product development processes, not only the integration between data management—motorized chassis, vehicle-traffic, but also the re-modelling and design of the comfort area of the vehicle from the driver to the passenger. The purpose of the research together with the development-oriented natural selection; the aim of this study is to analyze the effect of increasing comfort, vehicle and passenger safety in direct proportion to the decrease in travel time unit costs, and the efficiency of use of new automotive products driven by high technology, on lean product development processes, comparatively.

2. Autonomous Vehicle Technologies

The automotive industry is at the center of the design and production costs of autonomous technologies focused on increased value creation or reduced value loss, which are the current outputs of today's lean product development processes on new vehicles. Higher speed level autonomous vehicles, new bearings, more compact motors and faster inverter switches or frequency ratings seem to be potential options to improve performance [5]. Today's autonomous vehicle project targets at the aforementioned focal point, vehicle-passenger safety and e-mobility, high efficiency targets in travel time and comfort, together with high customer satisfaction and energy optimization, constitute new vehicle design inputs. Safety in autonomous vehicle design, which started with the aim of reducing traffic accidents; vehicle, driver, passenger, load, road, personal and data security are united under a holistic integration approach [6]. While it is foreseen that advanced autonomous vehicles will provide homogeneous travel distribution in the traffic flow; to provide more mobility for children, the elderly, disabled or low and low income groups, reduce the instant driving and navigation tracking of passengers, increase the fuel and part efficiency of the vehicle, reduce the time or space requirements between park and passenger, vehicle, passenger, road and increasing the level of personal security constitute the permanent new generation project goals. Diversifying transportation and transportation solutions in the focus of business model structure, especially as a service to increase the social sharing economy, has the importance of diversifying the economic benefits under the concept of new generation e-mobility.

In addition, security, road and vehicle technologies, social and brand responsibility, legal framework and government infrastructure regulations, which are important among the integration problems of autonomous products and environmental conditions under these concepts; the risk posed by hackers or vandalism, terrorism, similar privacy and security concerns; elimination of driving-related losses in the road transport industry has exposed the increased risk of suburbanization [7]. With the transition to the new life model in question, autonomous vehicle technologies; lane keeping, distance control, accident prevention, controlled automatic parking, electronic power distribution, cruise control or emergency braking and similar partial driving support structures have come to life in today's vehicles. However, on the one hand, the integration and development of fully autonomous vehicles and planned roads with driving support technologies continues on a firm scale in laboratory environments closed to traffic [8]. Today, many environmental infrastructure projects related to vehicle autonomy, magnetic field strips or periodic road information poles, continue at the vehicle-environment scale under artificial modelling of the environment. Autonomous vehicle control progresses in direct proportion to its satisfactory performance under significant uncertainties in the environment and its ability to compensate for system failures without external intervention [9]. With the participation of new autonomous technologies in the lean product development stages in the automotive industry, new disciplines and infrastructures, driving capabilities and connected systems, alternative driverless use scenarios or possible business cases, product or service structures have been re-modelled. With these innovations, the integrated life and service model triggers not only autonomous vehicles, but also alternative e-mobility ways, personal care robots, 3D printers, scanners or additive manufacturing, surveillance devices or near-future technologies [10].

New autonomous technologies developed and implemented under the automotive industry create vital value for future generations. Therefore, the distribution of responsibilities and regulations under legal stakeholders, which are of vital importance in the development and use of these new autonomous vehicle technologies, are revealed in the automotive industry. Legal stakeholders gathered under the aforementioned autonomous vehicles and environmental relationship: Vehicle (V), Pedestrian (P), Network (N), Infrastructure (I)/ Infrastructure, Connection (G) [11]. In this framework, the international legal regulations that continue to be developed or the stakeholders in the relationship matrix: V2V Vehicle and Vehicle, V2P Vehicle and Pedestrian, V2N Vehicle and Network, V2I Vehicle and Infrastructure have focused on the regulatory needs (**Figure 1**).

Especially today, the importance of secure V2N network communication speed, which creates low latency, of interconnected autonomous vehicles is emerging (**Figure 1**). V2N technologies encompass the rapid development and deployment of wireless technologies to provide real-time two-way communication between vehicles (V2V) and (V2I) vehicles and infrastructure (**Figure 1**). The convergence of sensor-based solutions, existing advanced driver assistance (ADAS) and connectivity (V2N) is essential for the sustainable development of autonomous driving. For a collaborative, safe, human-compatible traffic automation, decision, planning and control algorithms constitute a complex structure. For the digital modelling of the infrastructure of the traffic environment (for road automation) and its cyclical development, for the development of autonomous vehicles in practice, their physical, static and dynamic digital representations need to be standardized. In autonomous driving, the disappearing human influence, or factor, replaces technologies, while taking the role of a driver/operator, in simultaneous road and vehicle integration, recruiting into an automated road transport system, and creating new scientific definitions about understanding human interaction/interactions in all its aspects. In the development of fully autonomous vehicles (Level 5) in automotive industry companies, the path is divided into two: first, the improvement of automatic driving assistance systems found in today's conventional vehicles; the second depends in the reconsideration of self-driving vehicles and the environmental basic infrastructure [11] [12].

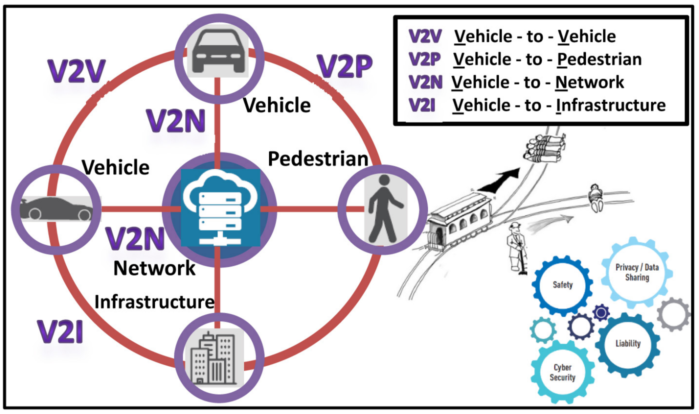

Figure 1. Legal liability in autonomous vehicles [11].

Therefore, many of today's autonomous vehicles with initial development content are provided with driver support by including adaptive cruise control as standard (**Figure 2**). Again, fewer vehicles of today's autonomous production include an active lane assistance system with partial autonomous feature (Level 2). In these future scenarios, in both systems with two alternative design orientations, a strategy based on actively developing driving support in vehicles with drivers is formed (**Figure 2**).

The fact that the vehicles manufactured to date and the cars and trucks with the new generation driving support system (Level 3 and 4) are driven in the same traffic pattern creates important technical, legal and conceptual approaches (**Figure 2**). The mentioned breakdown between partially autonomous (Level 3) and conditionally autonomous (Level 4) in **Figure 2** also shows possible usage scenarios between non-autonomous and semi-autonomous vehicles [8] [13] [14] [15] [16]. Therefore, a normative infrastructure environment classification, while providing fully autonomous vehicle use, becomes suitable for autonomous driving under fully defined conditions [13] [14]. The connected vehicle and connected infrastructure approach defines the entry level of high autonomy (Level 4) under the harmonized data syntax that provides usable data transmission frequencies, low latency, reliable and fail-safe data communication protocols, and interoperability in integration (**Figure 3**).

Today, in conditionally autonomous vehicles (Level 4), driving takes place without any real-time driver input, under very specific data, within a defined route and at low speeds (**Figure 3**). These highly autonomous vehicles (Level 4) have been implemented in limited use, mostly for trial purposes, including regional passenger cars and freight containers or, in some locations, public transport buses (**Figure 3**). Automated emergency response systems (AEIS), which fulfill all or part of the dynamic driving task in autonomous vehicles, but are not included in the defined taxonomy of SAE, have been used in restricted areas together with advanced driver assistance systems [18].

The ever-increasing need for comfort and safety in vehicles has forced manufacturers to invest more in R & D studies and to add new features to vehicles.

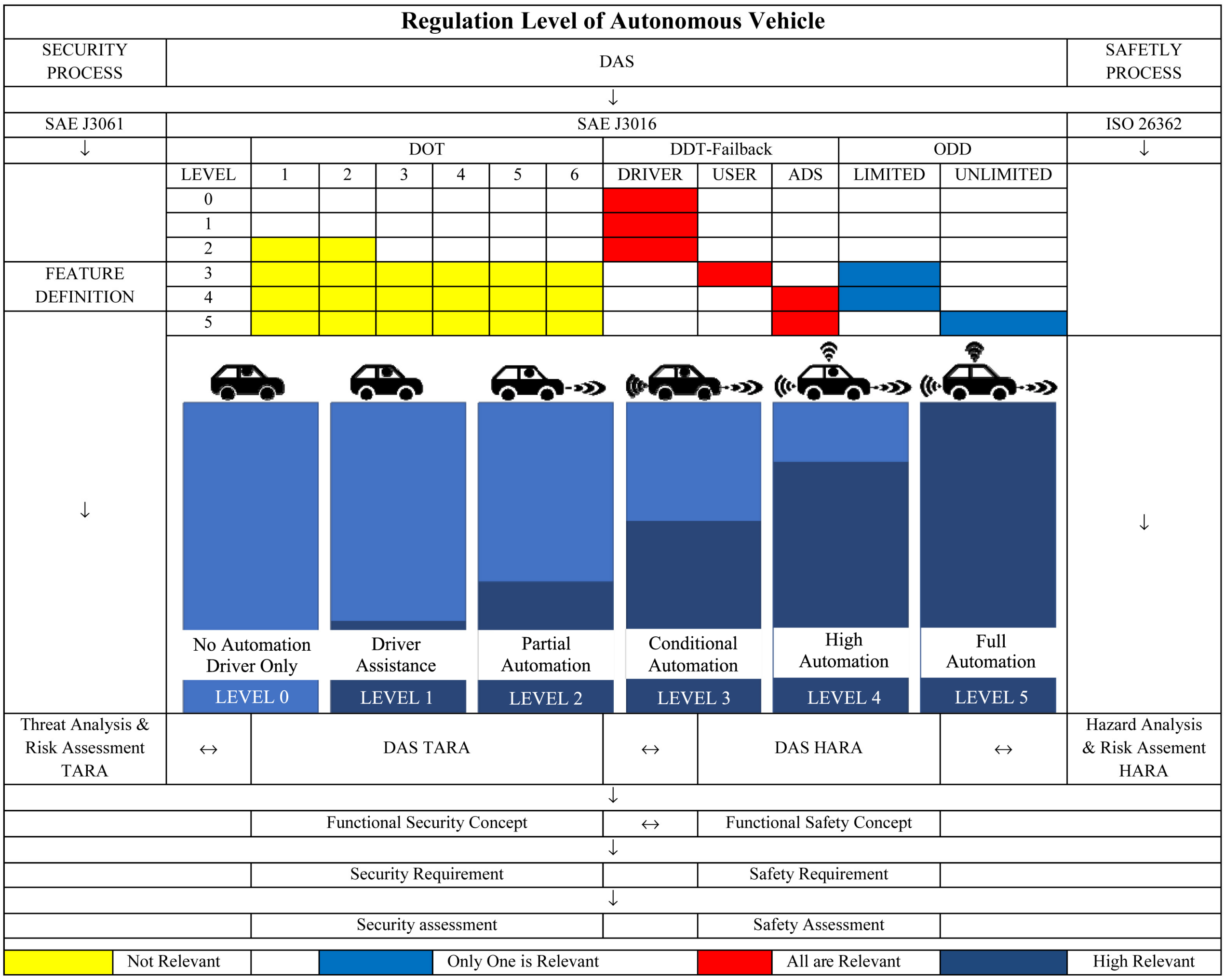

Figure 2. SAE levels of driving automation vehicle [8] [13].

Each feature with new functions brings an additional electronic module load to the vehicles or provides the development of an existing module. Increasing the number of modules assigned to the defined autonomous vehicle function, or equipping existing modules with more workloads, has transformed the communication of control systems from analog signal to digital signal over time [19]. The use of digital signals in today's communication channels has arisen from the necessity of reducing the density of existing or new cables on the vehicle (**Figure 4**). Therefore, this approach has given birth to a communication protocol called CAN (Controller Area Network) in vehicles, and communication between all functional units and systems takes place over this line (**Figure 4**). The CAN protocol includes the physical structure and working principle of serial and parallel communication (**Figure 4**). The CAN communication network on the vehicle and the data rates on this network are exemplified below [20].

The CAN BUS module (Controller Area Network), which provides indoor-outdoor communication in autonomous vehicles, is a serial communication protocol developed in the 1980's (**Figure 4**). On the other hand, although the CAN

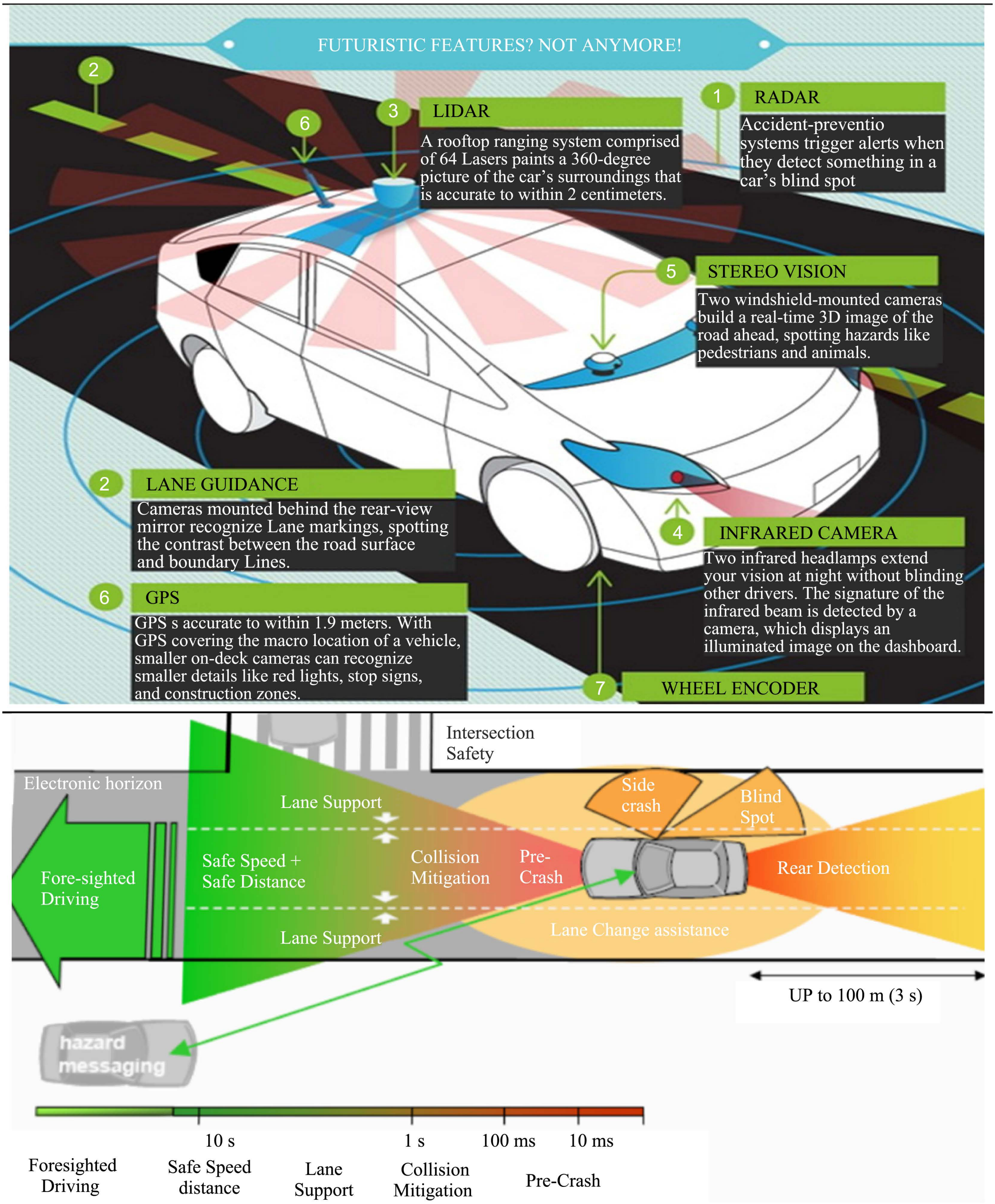

Figure 3. Data collection and processing in autonomous vehicles [15] [16] [17].

communication protocol is used in various areas of the industry, the automotive industry is the manufacturing sector where it is most widely developed (**Figure 4**). It is designed to realize the speed and security of information transfer

CAN (Controller Area Network)											
Class	**Transfer Range**	**AutonomousTechnologies**			**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 Telematics' 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			Cruze control				
		C3	BCU2	Body Control Unit-2							
		C4	TCU	Transmission Control Unit							
		C5	BSCU	Brake System Control Unit			Electronic thottle				
		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	Ultrasound		IEEE 1394	Steering angle sensor		BCM ECU METER		
		D10	WE	Wheel Encoder							
		D11	GPS	Global Position Navigasyon							
		D12	LKA	Lane Key Appoint		FlexRay	Display				
		D13	LG	Lane Guidance	Peak Data Rate						

Figure 4. Function-oriented communication protocol in autonomous vehicles [8] [21] [22].

between data communication modules of autonomous vehicles. The CAN protocol, the mechanical and hydraulic systems used have been replaced by electronic network structures and control units. In this way, the amount of cables used has decreased, the cost has decreased, the connection structure has been simplified and the reliability of the system has increased [23]. It is the communication medium, also called low-speed CAN (Low-Speed CAN), where the electronic comfort units, where autonomous vehicles perform their functions, are connected, and non-real-time or non-critical data flows (Figure 4). Any module connected to this line turns off its oscillators and goes into sleep mode when not used for a while. When a message comes from CAN again, it exits the sleep mode and continues to transmit information again [24].

As shown in Figure 4, autonomous vehicles have a total of 5 main input scarts, A, B, C, D, connected to the CAN line (Figure 4). As each input module is programmed, it uses the commands it reads from the CAN line, under the information it receives from the sensors, to manage the functional system it is connected to. In addition, for the integration of other modules when necessary, the use of the function under control in the system values is determined by instant data. For example, the task of the electronic climate control unit (ECC—Electronic Climate Control) is to control the heaters and coolers in the vehicle and to direct the related data to the CAN line. At the same time, turning off the air conditioner for a short time is coded by the ECC so that the engine is not strained while the vehicle is running. Although there is a lot of information about the vehicle on the B-CAN, all the necessary data for the speed controller is located on the C-CAN line (**Figure 4**). Because in the C-CAN line, real-time applications or time-critical information comes into play, not data that cares about comfort or periodic time interval or instantaneous response, as in B-CAN (**Figure 4**). As conveyed in **Figure 3**, 20 functions in the system; functional units such as engine control module (ECU-Engine Control Unit) and body control module (BCU-Body Control Unit) are connected to both communication lines as they are very necessary for the systems they are connected to (**Figure 4**). Although there are 6 connections on the C-CAN system module, it generates 18 different messages of periodic type. Therefore, each message on the CAN line carries at least one functional data. The data in question are: Vehicle longitudinal acceleration/Vehicle lateral acceleration/Vehicle angular acceleration (yaw rate)/Engine speed/Engine torque/Engine coolant temperature/Vehicle speed/ Different speeds of the wheels/ Gear position/Accelerator pedal position/Brake pedal status (correct addressing of the defined code of the information or message class on the CAN line it reaches) and similar codes and addresses are pooled. The address in the code message and other sub-information's of the data (offset value, resolution, etc.) constitute the reflexes of the decision mechanism. The structure in the subject sampling approach; the vehicle's gas pedal, ECU (Engine Control Unit), electric or diesel engine, injection system connected to the diesel engine, torque converter, gear and drivetrain, etc. trigger the system in common synch. In today's autonomous vehicles, the ECU (Engine Control Unit) is the central organ that processes data from many points through sensors and provides the most efficient management of the engine in changing conditions. Examples of the most common features used in autonomous vehicle systems are: surveillance, tracking, object recognition, and remote intervention [25]. Therefore, ECU is designed with microprocessor architecture and consists of its own processor, RAM, ROM, E2ROM, input-output and other peripheral units. Functions performed on autonomous vehicles: safety, comfort, efficiency, etc., are based on the continuity of reflexes, focused on instant data, under the decision-making mechanisms of similar approaches. The development of autonomous vehicle technologies continues on a function-based basis, without human guidance, using decision-making mechanisms. The integration of autonomous or non-autonomous vehicles, where main and intermediate control or ground stations can operate in a coordinated manner, under different types and sizes of sensors has become complex structures [26]. It is the central system that provides a safe transfer process without human intervention to the determined target in autonomous vehicles and uses its own decision-making algorithm thanks to electronic artificial intelligence while doing all these operations. They are compact structures that are guided by motion and action microcontrollers under decision-making algorithms in line with the data obtained by sensors, radar and lidar interacting with autonomous vehicles and objects. Therefore, microcontrollers can trigger and command obstacle detection, object detection, vision, motion system and control systems with developed software. With the autonomous vehicle-mounted laser scanner lidar, 360-degree vision is provided and instant images can be transferred. The Global Positioning System (GPS) antenna determines the current position of the vehicle and measures the distance to the target point. In addition, with laser scanners and long-short radars, it can identify other objects and vehicles, maintain the following distance, and enable communication with other vehicles and objects.

3. Lean Product Development Process Value Stream Map

After sequential new product development processes (Waterfall model) matured the manufacturing industry and gained the ability to manufacture, it turned into a time-oriented simultaneous process model under the rapid spread of mass and mass production or global competition. Today, in addition to the time variable, the simplification and value gain or preservation, which came into effect in the last quarter of the last century, under the resource management of innovation and efficiency parameters, gave rise to lean product development processes (**Figure 5**). Therefore, the lean product development model that comes to life in current industry practices: joint project model and room (Obea), joint and

1. Continues Improvement -Idea Management -PDCA-Cycle -Value Stream Mapping -Best Practice Sharing -Benchmark -Wikipedia -Trade-off Curves -Supplier CIP	LEAN DEVELOPMENT **Principles and Methods**	**5. Zero-Failure Principle** -Requirements Engineering -Quality Function Deployment -Quality Gates -Andon -Rapid Prototyping -Cardboard Engineering -Systematic Problem Solving
2. Standardization -Process standardization -Work standards -Categorization of projects -Quotes of reuse of parts -KPI system	**4. Flow and Pull Principle** -Process Synchronization -Process oriented Project organization -Competence canters -Regular communication -Simultaneous Engineering -Supplier Integration -Request for Design and Dev. Proposal -Systematic supplier selection process	**6. Leadership and People** -Failure and No-Blame Culture -Coaching -Qualification Planning -Mentoring -Leadership Standards -Specialist Careers -Strong Project Leader
3. Visual Management -Visualization of Project contents - Visualization between areas -Go-to- Gemba -5S -Project Monitoring		**7. Frontloading** -Optimization of portfolio -Target Costing -Life Cycle Planning -Set-based Engineering

Figure 5. Lean product development process principles [27] [28] [29].

virtual product development environment (PLM), full, fast and visual project communication (A3), standardization of processes and value-oriented mapping, project objectives and innovation-oriented management has revealed similar flow approaches (**Figure 5**). In addition, today, lean product development process design and development structure is evaluated by scaling under the value gain or preservation in lean [27] [28].

As explained in **Figure 5**, value creation or preservation for lean product development is measured under 7 main headings [29] [30] [31]. In addition, although the 7 basic and 13 sub-principles in question increase in applications and researches related to lean product development, since the starting point of the main approach is lean criteria, the focus in the study is the new interdisciplinary transition (design verification) stages caused by autonomous vehicle technologies (**Figure 5**). In the entry-level applications in the automotive industry, the process flow type, efficiency in resource management (work-time-saving) are evaluated together with the design of the part-system-function that adds innovation to the new product under the standard process structure (functions that the customer pays for). Therefore, to activate the pull system for the continuity of the design stages that create or protect value, then to be able to separate the waste created by the lean product development steps, to drag all the stages under the influence of the push system creates a repetitive structure in the work [28] [30] [31] [32]. In addition, in the table above; 1) Sustainable development (Value Stream Mapping), 2) Standardization (KPI System), 3) Virtual Management (Value Creation Field Detection/Gemba), 4) Pull and Push principles (Changing Design/Value Requests), 5) Zero Defect Principle New product development for (value creation with goals), 6) Leadership and employee definitions (Culture Change), 7) Frontloading of information (Definition of design verification criteria) approaches are transferred to the process in a holistic structure by constantly renewing target-oriented high-efficiency flow steps (**Figure 5**). On the other hand, these ideal lean design steps started with taking a snapshot of the current situation for value acquisition or creation in the process flow and formulating the needs after defining the real situation. The initial step for the transition to the said lean design model is revealed by collecting systematic real data from the field and setting up the measurable analysis structure in practice, then configuring the formulas based on all stakeholder disciplines and interdisciplinary transition verifications to determine the common metric unit value, scale and enable new product development process diffusion. However, the first step of simplification and lean product development begins with the determination of the importance of the current value of each discipline or specific work that constitutes the process, including the process, and the definition of the metric scale unit and the level of importance within the whole structure. The outsourcing decisions of very important or time-consuming businesses can also be defined in this scale economy stage. The definition of scale value under the common metric unit of every work, every part, every function, every discipline, every test and analysis, which is included in the resource management of new product projects developed in the automotive industry, ultimately reveals the size or level of the project to be started. Therefore, the formulation of the project or its scale, planned from the beginning, on a metric unit, the step-by-step definition of resource management, reveals the process value structure and flow map. Workflow for each discipline in the lean product development process: the project continued with holistic work under the definition of initial objectives and testing or analysis (verification under variable scenarios) of parts including the new autonomous vehicle function as part of the whole on the new product. In this framework, autonomous vehicle design is involved in the process as much as the variables that do not input information and do not add value to the development stages (protection or control-oriented process disciplines), except for studies involving innovation, new technology, parts or system functions (**Figure 6**). If we approach it from a

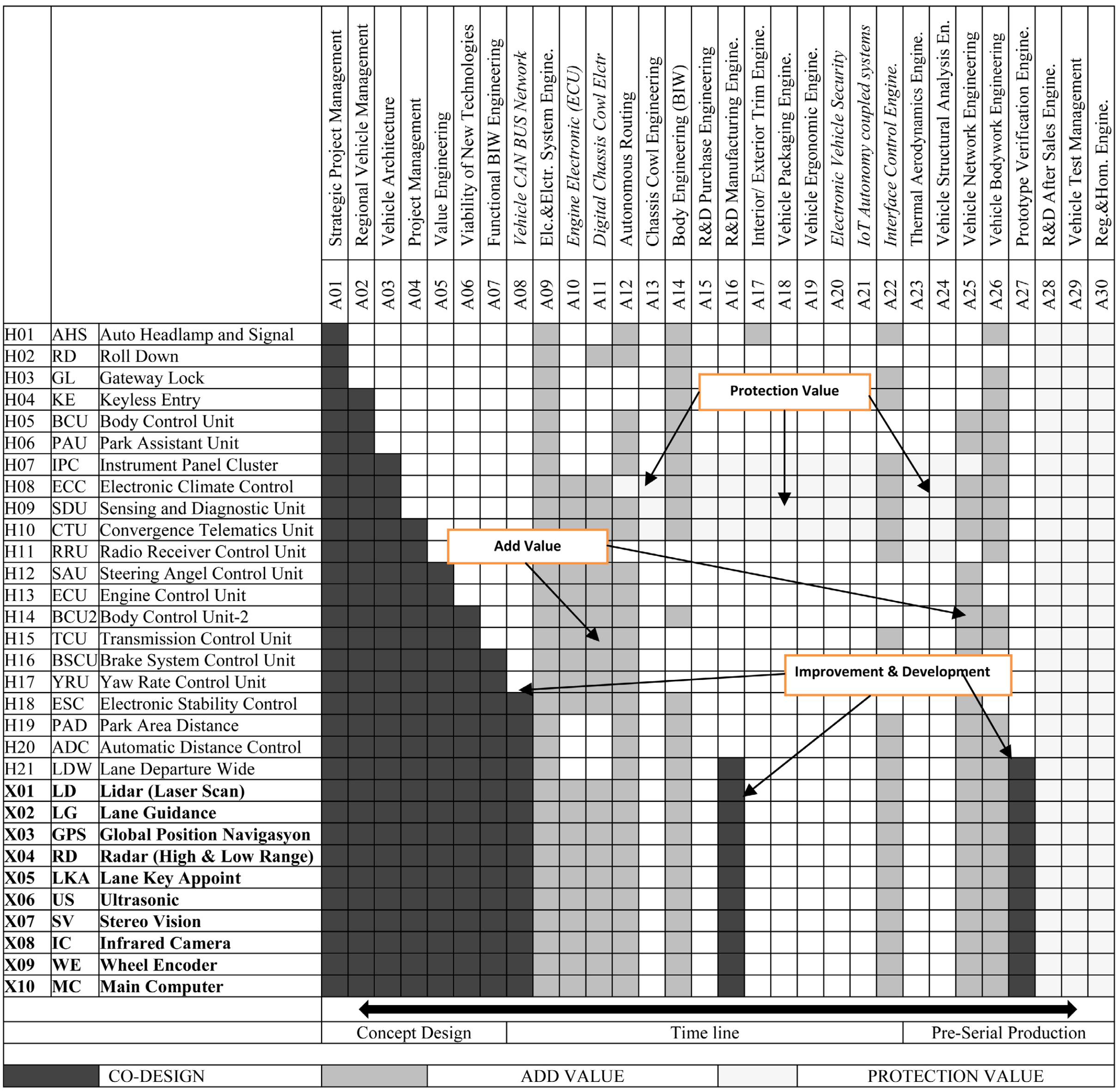

Figure 6. Lean product development process for the value stream.

different angle, all product development stakeholders or studies other than the use of the pull system in the lean product development process flow, new disciplines or businesses that will develop new functions in the autonomous vehicle project goals constitute the waste part of resource management. As emphasized in **Figure 6**, the test and validation workload created by the probability scenarios in new autonomous vehicle function or part applications that are included in the lean process flow with innovation goals reveals the basic formation of the value stream map. On the other hand, design verification, testing and analysis studies between lean product development phase transitions lead to the value chain propulsion system if a common metric or scale is not determined in autonomous vehicle projects (**Figure 6**).

The new autonomous vehicle disciplines and technologies that make up the lean process flow, the project metric value or scale to be structured according to common interdisciplinary business indicators: it maps the losses in the value stream, the company's new technology creation steps, the limits of value preservation and application, and its ability to adapt innovation (**Figure 6**). The lean autonomous vehicle project process equipped with new technologies, along with the inclusion of existing and new disciplines in the flow, formulates the value creation under the flow map, as well as the metric importance coefficient or scale definition that will cover every stakeholder of the process, as well as increasing the efficiency of the innovation in practice [30] [31]. The targeted innovation in the new autonomous vehicle design provides diffusion and experience by reducing uncertainties by formulating new technologies and disciplines, efficiency calculations that can be added to the existing value stream, or metric importance factor, scale ratio, defined project sizes in the existing lean stream (**Figure 6**). In this case sample, the research generates outputs to describe the efficient setup of autonomous technologies and disciplines, which come into play in the new vehicle design and lean product development process, which are comparatively realized in global and local automotive industry companies (**Figure 6**).

3.1. Key Features of the Value Stream

In the lean product development and autonomous vehicle design process, the formation of the value stream map, together with the integrated data communication system control, the status determination of the current process flow or the application of resource management according to the project sizes (new part, system and function matrix) repeated at certain time intervals, the importance of the new function scale, the project begins with the definition of the metric unit. Lean project value stream under the target of implementation and development of autonomous vehicle technologies, design validation acceptance criteria or project metric unit, which constitute new process stakeholders, take place in new disciplines and interdisciplinary transition steps (physical or virtual test and analysis joint studies of autonomous vehicle technologies), and the common value in the scale reveals the total success rate in the targeted results of the project. Therefore, determining the weight of new disciplines to be added to the existing lean product development process (disciplines that include the development of autonomous vehicle technologies), software and hardware that includes mathematical function analysis, the total workload or the intermediate specializations it affects, in terms of metric units that make up the value stream, the effect on the value map measurement has important implications. The basic approach of lean is that processes and studies that do not add value or cannot be measured are not included in the lean product development flow, creating a prerequisite for increasing project efficiency or maintaining value. As mentioned in the first section, the platform created by new autonomous vehicle technologies in the automotive industry consists of dynamic security, comfort and efficient energy functions based on data transmission and processing speed. Under the aforementioned artificial and digital perception, instant data acquisition, instant data processing and instant dynamic orientation according to the data have revealed the restructuring and editing of the integrated systems of the autonomous vehicle design according to the environmental conditions. On the other hand, the concept, which is the first project stage in which the targets are transferred, is observed holistically in the development of the concept automotive design, in which the steps where innovations can be applied are defined and the whole flow is planned in the projects where new disciplines including autonomous vehicle technologies will be included in the lean product development process with their needs, requirements and prerequisites. The fact that the autonomous vehicle technology needs are in the first step of the lean product development project process and that they are revealed in the basic process particles or the holistic formation of the main structure supports the lean approach, as well as includes defined problem-solving methods and detailed measurements under the metric value [33]. The lean management approach that automotive industry companies develop and maintain today; integrates existing product development stages, autonomous vehicle technology expertise that comes into play with new technologies, new subsets or disciplines, together with project efficiency calculations in the value stream and project metric unit. The common metric value or defined project scale, which includes new value stream information and needs (autonomous vehicle, test and verification software or hardware) focused on resource management (time and workload), which is the main subject of the basic value stream, primarily in the phase transitions that form the interdisciplinary common structure focuses on design validation studies. The new product development or automotive design initial stage transition criteria, which are included in the same approach, play a guiding role in revealing or updating the roadmap of the whole process with a holistic perspective. With the integration of new autonomous vehicle technologies, in addition to the improvements in the existing lean product development flow discipline, the parts or systems of new autonomous technologies supplied from outside the company, together with the expertise reports of all relevant departments, determine the in-process position of new disciplines in the result-oriented value stream. In addition, the momentary deviations, modification changes or interdisciplinary negative effects of the periodically updated lean product development processes in the value stream change the entire project scale and the direction of the value stream by providing information input to the expertise or project stages that it drags instantly, by connecting it. To connect all project stakeholders with value stream, lean tools, lean metrics, new autonomous technology applications and structural priorities for integrated transition or update to lean product development and automotive design processes with new autonomous technologies and disciplines, to update design validation criteria in phase transition provides benefits. In this framework, the frequently updated lean product development processes and stakeholders of global and local automotive manufacturing industry companies, which are the field participants of the study, were clustered according to their specializations and formulated on a deep common denominator under the design verification criteria. On the other hand, when we match the current autonomous vehicle driving with human perceptions; the collection of pre-perception-information for vehicle driving, based on the instantaneous data flow rate of this information, creates a holistic approach that provides the instant decision mechanism and the continuity of this instant decision in vehicle steering. In addition, continuous flow is created by processing instantaneous perception structure and instant flow information, vehicle equipment, physical infrastructure, physical-digital infrastructure and instant data created by digital infrastructure (Figure 7). The approach in question develops in a similar structure in today's autonomous vehicles and constitutes the integration of four basic units as seen in the appendix: sensors, data processing center, decision-making center, drivers and actuators have configured the basic system (Figure 7).

With the instant external environmental communication infrastructure information created by sensor technologies, the route entered into the main processor of the vehicle directs the digital motorized chassis or steering actuaries in

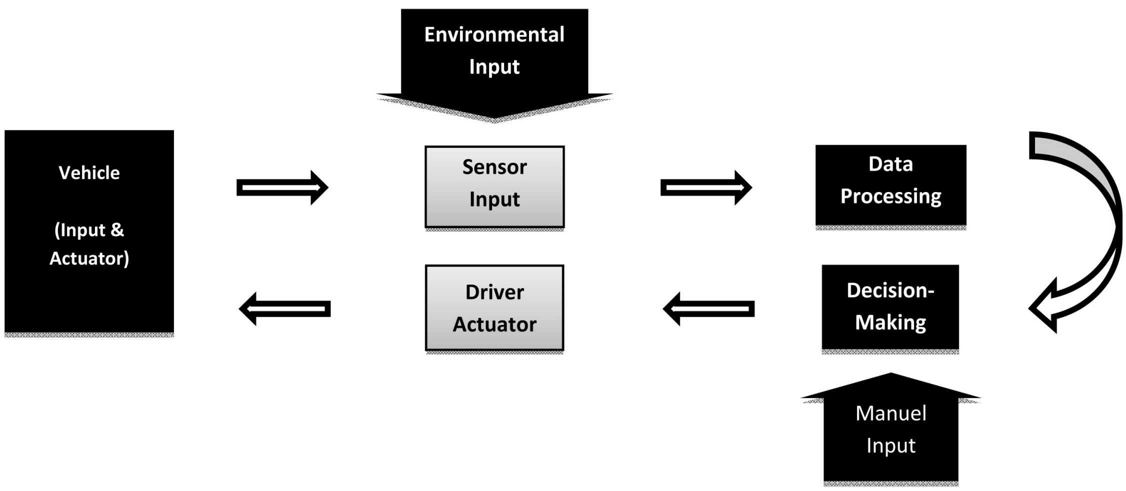

Figure 7. Decision making flow in autonomous driver.

a speed-time oriented manner (**Figure 7**). Sensors or external sensors convert very different information into electrical coding signals and transfer them to the next decision-making mechanism (**Figure 7**). The decision-making unit connected to the main processor of the autonomous vehicle is oriented by clustering the data coming from the sensors into a very large and complex format (orientation angles depending on speed and load). The interpretation of these directly by the decision mechanism and then directing them to a decision accordingly proceeds in direct proportion to the data communication speed of the system (**Figure 7**). The workload created in the system integrates with the secondary support unit to decide the next alternative autonomous driving route. Decision-making algorithms are positioned as speed-oriented in the main central processors of autonomous vehicles. The main task of the decision-making mechanism is to process instant external data and test the accuracy of digital communication information with all sensors by cascading them relative to each other in a time-oriented manner. The data collection and processing center in autonomous vehicles, after decomposing the complex and heavy load (voice, video and signal, etc.) data collection into a simple and regular form, transfers them to the decision-making center at regular intervals. The said decision-making mechanism determines what the vehicle should do, at what speed and in which direction it will go, after evaluating the first request of the user and the sum of the information coming from the data processing center. As a result of this process, the actuator drives the drivers and thus the digital actuators (digital motor chassis bodies). Therefore, digital drivers dynamically direct the functions of the vehicle (gas, brake, gear, ignition, steering) according to the reference information and values that come to them with their control algorithms. In today's automotive industry, heavy global competition focused on up-to-date product development progresses in two different ways: alternative energy sources or digital driving support systems. Under heavy competition in the automotive manufacturing industry, the development and use of alternative energy sources progress from global suppliers, while software development shows a company-specific development. On the other hand, the development in the second main topic, which differs in the said competition, continues in the classified regions for advanced imaging and sensor processing technologies, adaptive decision algorithms, high-definition mapping and some special case or road conditions, which they have partnered with global technology development and supply channels specific to automotive industry companies. While autonomous vehicles (Level 4 - 5) operate almost exclusively in self-driving mode in defined traffic zones in many countries, trial use continues on completed long-distance highways and arterial roads tailored to top-of-the-line fully autonomous vehicles [34]. Therefore, the integration of technically controlled special road conditions into new product development processes and the adaptation of existing technologies for highly autonomous driving have come into play. State-of-the-art sensors (radar, lidar, lane, GPS and camera vision systems, etc.) are used, along with high-precision maps that allow the on-board systems to identify obstacles and related signage, as well as the use of roads in suitable navigation conditions.

3.2. Main Structure of the Value Stream

Lean process steps, which come into play with new autonomous vehicle technologies and are modelled under the value stream created by new expertise, reveal the bond formula between new product development and design transition steps, and define the continuity and cycle of development up to manufacturing. In the process of lean value stream and new product development, value creation or preservation consists of eight main topics, features as explained in Chapter 2. These 8 basic features are; a-Simplification, b-Value stream decision selection, c-Lean deployment, learning, d-Current state analysis, map, e-Lean metrics, common unit, f-Future state synthesis, roadmap, g-Kaizen plan, foresight, h-Kaizen plan, implementation, etc. [33]. Under the scenarios revealed by the design validation phase transitions in the value stream, new autonomous technology expertise is updated together with lean product development management, with the simplification of all automotive design activities of automotive industry companies. Therefore, simplification provides value-oriented (metric common unit) control of all new product development and automotive design activity steps or design verification phase transition approval processes. In this direction, the participating automotive industry company managers in the fieldwork formulate the flow by including the application stakeholders in the process, together with the supplier that realizes the development of technology at the scale of the project metric unit, within the existing living system steps, instead of directly involving the new autonomous vehicle expertise in the process. Therefore, new autonomous technologies in the bare value stream include radar (short-long wave), lidar, sonar, ultrasound, lane, GPS, wheel encoder, high-resolution camera and display processors, as well as high-speed internet-based data exchange and management (**Figure 8**). In addition, they are dynamic holistic flow solutions that ensure the continuity of their own decision-making action based on the data generated by environmental electronic perceptions by providing their own system integration in the light of various sensors, audiometers and moments of inertia measurements (**Figure 8**).

As mentioned above, the process under the information input and output of the system, which consists of 8 new autonomous vehicle technology pieces in an integrated structure, forms the basis (**Figure 8**). These new autonomous vehicle technologies are used for instant data acquisition and transfer information to the vehicle's decision-making mechanism (**Figure 8**). It has advanced continuity (path/time) and includes rapid decision making (m/s) or environmental identification and analysis under the integration of control systems; instantly under integrated algorithms of the information collected to identify roads, living and inanimate objects, speeds, regions, fuel-road ratios, obstacles and related traffic laws and signs, to identify current or near future, instant space and time, to calculate probability or includes instant reflexes under integrated algorithms of information gathered to guide (**Figure 8**).

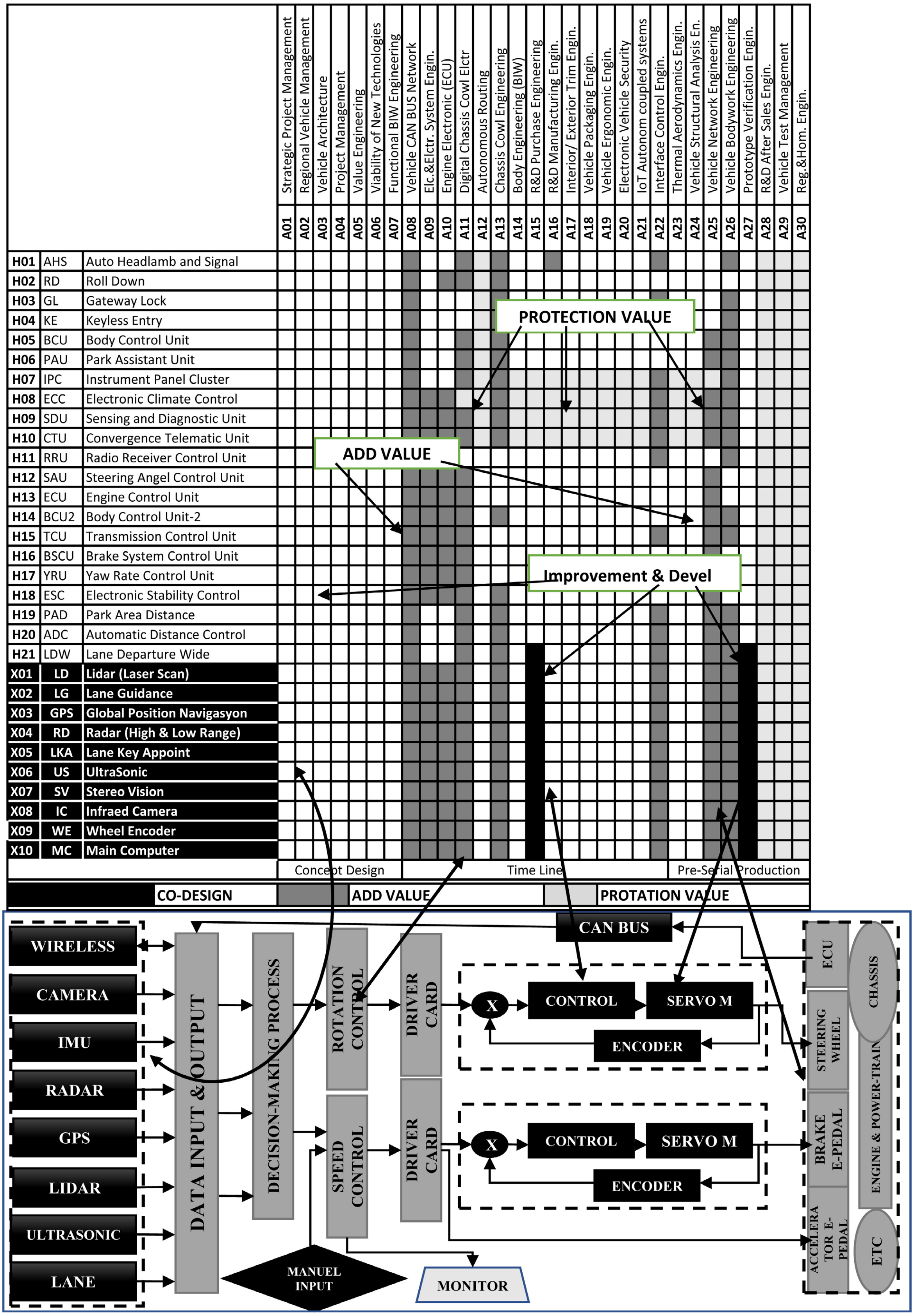

Figure 8. Autonomous vehicle driver input & actuator system.

4. Research Method

Field studies, together with the new product development process managers (10 from each participating company, 60 company managers in total) realized in 3 local, 3 global, 6 automotive industry companies with different organizational structures operating in the same location, with repetitive plans, completed under the definition and comparison of common values in new vehicle projects. Definition and comparison has been completed under the headings. Today, the inclusion of new autonomous vehicle technologies and new expertise in the defined existing process, the spread of lean product development metrics specific to the automotive company, and the new process models, which can be measured under the quantitative results of the AHP mathematical model survey, after qualitative one-on-one interviews in the field, have revealed a mixed field study [34] [35]. Although the lean process flow caused by the new autonomous technologies, which is the subject of this updated research, did not develop in a planned manner, the mixed research method was preferred in this study as the methods used in the first research were successful. As in the first, in the plan and implementation of the second field study, how the autonomous vehicle technologies that have just been introduced in automotive design, together with the lean product development process, penetrate national and international industrial companies, were examined under the AHP mathematical model questionnaire. The analysis of yesterday and today on the basis of yesterday, today and future process scenarios, together with the value stream map in the lean product development process under a helical approach, yields important results in future configurations. The aforementioned two-stage new fieldwork has revealed the value flow, efficiency, mapping and design validation parameters experienced in the lean product development process in the innovation-oriented application under the new autonomous vehicle technologies.

5. Value Flow of Comparative LC-GC Automotive Companies

As observed from the field research, autonomous vehicle technologies show rapid development under two main headings, passenger and vehicle safety systems. As determined in the field, the first basic development is time and space oriented digital sensing function (Lidar, Lane Guidance, Stereo Vision, Ultrasonic Sensors, Wheel Encoder, Short-Long Wave Radar, GPS, Infrared and HDR cameras, with definition of vehicle driver functions, Graphics Cards and Processors, etc.), digital communication parts and systems. The second basic development topic determined in the field study is the support software and hardware applications that can transform autonomous driving, vehicle orientation into instantaneous response under time and space-oriented digital perceptions (processing of perception by converting it into information and orientation or speed-oriented part design and system development in motorized chassis). However, another important issue that emerged in the field research shows the sustainable energy needs of vehicles or the development of alternative environmentally friendly energy sources in common with autonomous vehicle technologies. The new driving characteristics of autonomous vehicles in the motor chassis part, together with the time and location variables, have classified the autonomy levels and regions at the initial level of the international automotive industry regulations depending on the use of alternative energy. Although international regulations, in principle, have already developed this classification in detail on vehicles within the partially autonomous (Level 3 - 4) or fully autonomous (Level 4 - 5) driving functions, during the next step of autonomous driving, it will be more developed in vehicle driving skills. Little change is observed (more, national and international legal or infrastructure regulations are expected). Autonomy in vehicle driving has led to the need for software and hardware that control the transverse and longitudinal driving dynamics of the vehicle with high precision, due to the necessity of determining the position at a defined speed together with the vehicle speed and reacting simultaneously to internal-external variables (traffic conditions).

Along with the autonomous support systems included in the current supplies of automotive industry companies participating in the fieldwork, various software and hardware services that create joint investments are prominently revealed [36] [37] [38]. Digital technologies in shared use network and communication in this autonomous vehicle development (**Figure 9**): sensors, vending

CODE	Autonomous Vehicle Functions			Class Transfer Range
H01	**A1**	AHS	Auto Headlamp and Signal	**A-CAN** 10 Kbps
H02	**A2**	RD	Roll Down	
H03	**A3**	GL	Gateway Lock	
H04	**A4**	KE	Keyless Entry	
H05	**B1**	BCU	Body Control Unit	**B-CAN** 10 Kbps - 125 Kbps
H06	**B2**	PAU	Park Assistant Unit	
H07	**B3**	IPC	Instrument Panel Cluster	
H08	**B4**	ECC	Electronic Climate Control	
H09	**B5**	SDU	Sensing and Diagnostic Unit	
H10	**B6**	CTU	Convergence Telematics Unit	
H11	**B7**	RRU	Radio Receiver Control Unit	
H12	**C1**	SAU	Steering Angel Control Unit	**C-CAN** 125 Kbps - 1Mbps
H13	**C2**	ECU	Engine Control Unit	
H14	**C3**	BCU2	Body Control Unit-2	
H15	**C4**	TCU	Transmission Control Unit	
H16	**C5**	BSCU	Brake System Control Unit	
H17	**C6**	YRU	Yaw Rate Control Unit	
H18	**C7**	ESC	Electronic Stability Control	
H19	**D1**	PAD	Park Area Distance	**D-CAN** 5 Mbps
H20	**D2**	ADC	Automatic Distance Control	
H21	**D3**	LDW	Lane Departure Wide	
X10	**D4**	MC	Main Computer	
X07	**D5**	SV	Stereo Vision -Video	
X08	**D6**	IC	Infrared Camera	
X01	**D7**	LD	Lidar (Laser Scan)	
X04	**D8**	RD	Radar (High & Low Range)	
X06	**D9**	US	Ultrasonic	
X09	**D10**	WE	Wheel Encoder	
X03	**D11**	GPS	Global Position Navigasyon	
X05	**D12**	LKA	Lane Key Appoint	
X02	**D13**	LG	Lane Guidance	

Figure 9. Autonomous vehicle technologies [8] [21] [22].

control and payment, software, servers, power supplies, wireless networks, short-distance vehicle-to-vehicle communication, long-distance map access, software upgrades, road reports, navigation, global positioning systems (GPS), custom high-quality maps, and the development and manufacture of subcomponents with critical element, test or maintenance use (**Figure 9**). On the other hand, subsystems and parts in the main system and supplier development in autonomous technology with common use, in vehicle and passenger safety; hardware and software corruption, unauthorized use or hacking of vehicle and traffic information systems, increased risk occurrence and consecutive multi-factor probabilities, increased average travel times, additional risks to non-vehicle passengers, reduction of investments with traditional safety strategies, and similar common approaches are excluded (**Figure 9**).

Included in the research, 3 global (GC) and 3 local (LC), a total of 6 automotive industry companies that design, develop and manufacture vehicles in the same class under heavy competition in the same regional market, partnering with the lean product development processes, are shown in **Figure 9** are listed with value stream criteria under cross matrix with domain autonomous technologies. The main variable in the value flow criteria with common use, which constitutes the depth of the study, is in the structure of autonomous technology development, test and analysis procedures in GC automotive industry companies, while commonality in autonomous technologies outsourcing and external supplier development processes in LC automotive companies. Therefore, departments and specialties involved in autonomous vehicle technology development were evaluated through two different processes and two different methods in lean value stream mapping. The comparison AHP model structure in the second part of the research followed a path compatible with the first comparison structure that created the value stream mapping. The fact that 6 automotive industry companies that participated in the two field analyses of the research had lean product development processes and value stream maps made all stages of the study more understandable. The study was designed with the statistics of the region preferred in the research, ranking 12th in the world commercial vehicle market, having a say in global manufacturing and market share, retrospective recorded market share developments and product numbers of the 6 selected automotive industry companies.

5.1. Value Stream Map of LC Automotive Industry Companies

In the light of one-to-one interviews with 30 managers of 3 automotive manufacturing industry companies (LC) (3 × 10 managers from 3 local automotive manufacturing industry companies, 30 employees in total) in the comparison structure of the field research, interdisciplinary step transitions where autonomous vehicle technologies that create workload in lean product development studies are matched, the attached matrix is listed in common in **Figure 10**. When the lean product development process and expertise of LC automotive manufacturing industry companies are examined, it has been observed that the

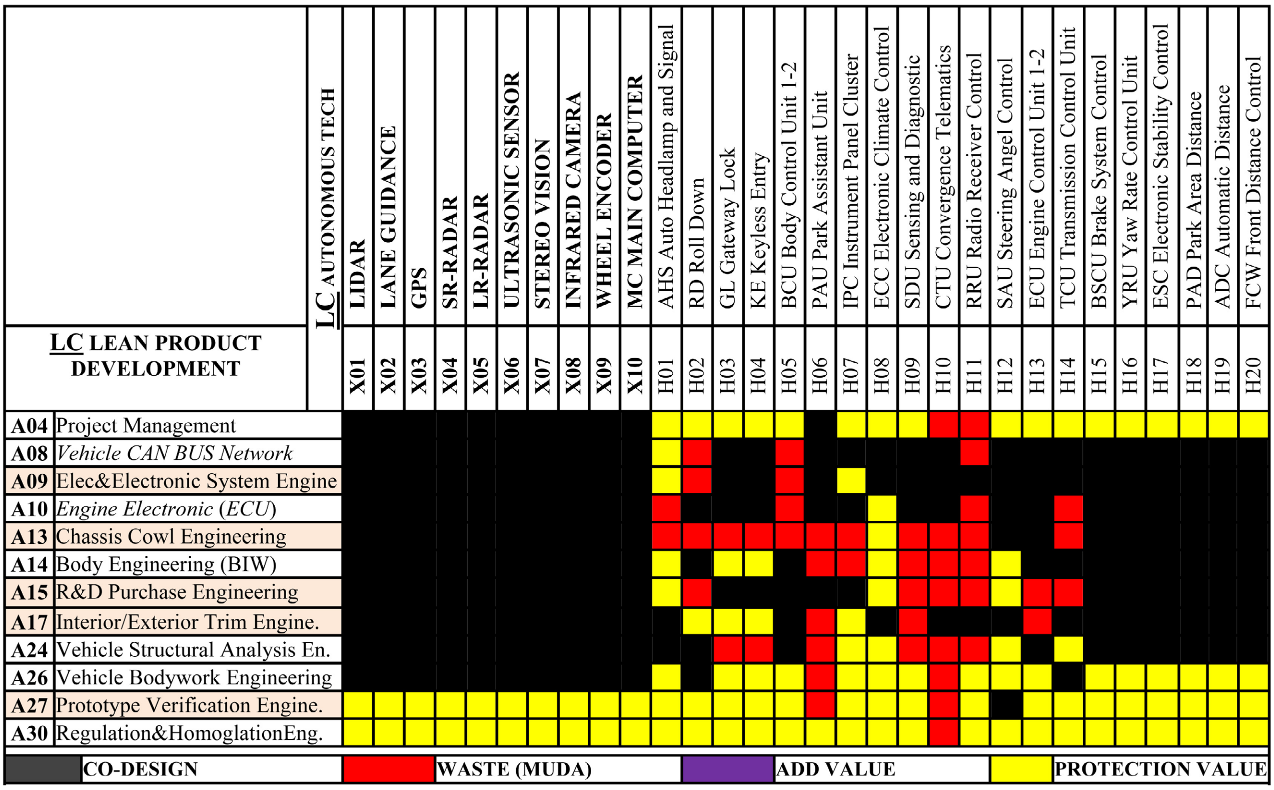

Figure 10. The stages of collaborating in the value stream in the LC lean product development process.

functions of the new autonomous technologies are controlled from the vehicle main processor CAN BUS system, and the stages that progress in the value stream of step-by-step analyses create a multidisciplinary repetitive workload. It develops the digital vehicle technology development of LC companies over the CAN BUS vehicle motherboard in the computer environment, software engineering analysis and coding tests, on a common platform with the part supplier. In addition, digital motorized chassis guidance equipment, which extends to road tests, was revealed in one-on-one meetings with lean product development managers, which they started to acquire through the supplier channel on a common platform. While new project targets in LC companies are determined through competitor and new autonomous regulations, lean value stream, common product lifecycle (PLC) develops with modification according to 3D virtual prototype application and test results on digital network. Since the local automotive industry companies (LC), which constitute the comparison structure of the research, supply the digital motor chassis part of the vehicle to a large extent from external supply channels, the function adaptations of new autonomous vehicle technologies over the CAN BUS system constitute the focus of lean product development studies (**Figure 10**). In addition, different functions of different supplier companies that develop the same autonomous technology or sub-parts in the procurement-sourced lean product development process in LC companies, matched with different codes, create important application errors in the integrated structure (**Figure 10**).

In the light of one-on-one meetings with LC, part-based outsourcing of autonomous technologies or partial adaptation to the new vehicle structure has revealed the correlation of systems and functions that basically work together (**Figure 10**). The fact that the said outsourced technology, parts and functions perform their duties independently or alone creates an adverse effect and waste in probability calculations and value streams in test or usage conditions (**Figure 10**). Therefore, the basic approach in autonomous vehicle projects carried out under outsourcing technology, parts or systems in LC companies; it is flow modelling from scratch by identifying new or autonomous technologies in practice, updating the design validation phase transition variables and boundaries within the existing process structure (**Figure 10**). This approach gives rise to different solution methods under the definition of co-design research and development project, collaborations that can be formed with the definition and tolerance of interdisciplinary transition steps, joint tests and analyses, and probability calculations, instead of LC lean product development. In addition, the transfer of ready-made technology to the high-level autonomous vehicle projects continuing in the supply channel of LC companies and adding the value stream accordingly, the design verification phase transition test and analysis needs or their positive and negative effects on the vehicle can be renewed over the existing flow, just as in autonomous stages. It has been observed that it is used to determine the level of the project. On the other hand, the attempts of LC automotive industry companies to determine project size and stage in new product development processes, and the definitions of the project stage in question; investment amount, target market structure, time, resource management created by the workforce and similar market-time-oriented variables are among the findings within the scope of the research they planned to define the investment balance. In addition, new product development project stage matrix and code definitions in LC companies, part-based levelling systems, which are in parallel with autonomous vehicle levels, which they put into use by taking GC companies as an example in their autonomous vehicle technology adaptation studies, have recently been included in the system. Similar project size and code definition or project level remain in LC local automotive company meetings, manager experiences, but projects are carried out with cost-oriented calculations, mostly through suppliers that develop autonomous technologies and technology acquisition.

In LC local automotive companies, although autonomous vehicle technologies are included by suppliers on new products, relevant specialties or departments have started to be involved in field or computer analyses for technology testing and analysis. The said LC plans needs analyses (software, hardware and related test structures in the same network as suppliers) for newly established specialties or departments in local automotive companies for increasing levels of autonomy and technologies. The existing lean product development processes and disciplines in GC and LC automotive companies update the new vehicle product with joint or instant designs in the digital environment, and facilitate the transition to the interdisciplinary structure created by new autonomous vehicle technologies. In the field study of the research, GC global automotive companies focus on design validation (testing and analysis) variables in transitions between lean product development stages, while LC companies focus on part-oriented adaptations of autonomous vehicle technologies. The approach brought by this habit is due to the modular link transition structure in the value mapping structures with the defined project levels that are ongoing in GC automotive companies. LC automotive companies, the other polar opposite in the comparison structure of the study, linked the secondary value protection function to all the knowledge under part-oriented developments on the definition of common system structures or the measurement of the interdisciplinary effects of lower-upper limit values. While the new part-oriented autonomous vehicle technology adaptation is at the forefront in the lean product development structures of LC automotive companies, their failure to reflect this situation to the process development or not to develop a flow model specific to this flow has revealed a new part-specific value map containing each autonomous technology. This situation constitutes the first core structure of lean product development, the cycle of just-in-time and adequate limit information flow between the design validation steps, which has a negative impact on the function-oriented value stream for which the customer pays.

5.2. Value Stream Map of GC Automotive Industry Companies

In one-on-one interviews conducted with the employees of global automotive industry companies (GC) within the scope of the research (30 employees); Process and interdisciplinary value flow variables were discussed over the autonomous vehicle technology applications realized with lean product development project management, related tests and analyses, or current ongoing new product development studies. In one-on-one interviews consisting of open-ended questions; the focus is on new or differentiated stages, showing how they affect the value stream in existing lean product development processes, updated with new autonomous vehicle technologies. According to LC companies, since GC automotive manufacturing industry companies are both the main partner of the suppliers that carry out the production and development of motor chassis parts, and the main stakeholder and application responsible of the team for the design of new autonomous vehicle technologies, lean product development project goals are more clear and consistent. GC automotive manufacturing industry companies, which are responsible for the design and development of all 30 autonomous vehicle technologies identified in the first section, played a leading role in determining the current value stream map of the lean product development process.

In the comparison structure of the research, the integrated roadmap in GC companies both defines its own internal process operation and plays an important role in revealing the link functions of the unit values of autonomous functions and digital parts that require value preservation. The test and analysis, information or findings, which are responsible for the design and development of the said new autonomous vehicle technologies or which include the results of field application through the sub-supply brands of these technologies, form the future competitiveness of the automotive industry, step by step. In the face-to-face interviews of the first fieldwork conducted with GC automotive company executives, the newly created value stream map of autonomous vehicle technologies over the existing process was defined (Figure 11). It coincides with the negative and positive effects of disciplines that are newly involved in lean product development steps or new vehicle functions, where the participants explain

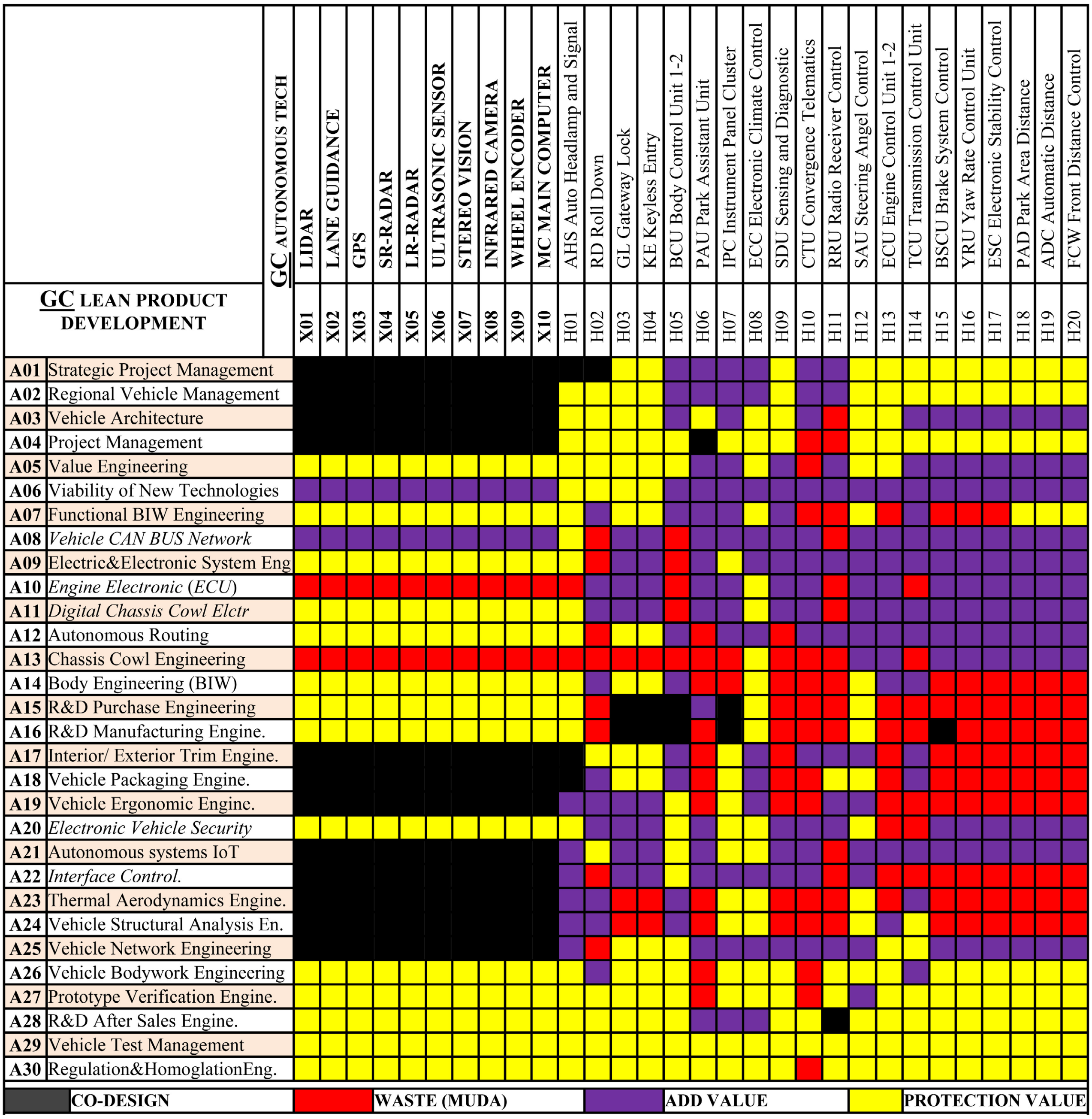

Figure 11. Collaborative stages in the value stream in the GC lean product development process.

the working time and location of autonomous innovations, especially in the initial project goals, in harmony with each other. The current lean product development value stream of GC companies creates definitions of value creation that include autonomous vehicle technologies that create innovation according to their current processes in use or that match project objectives. Therefore, determining the definitions of adding value or protection, calculating the project size based on new parts and functions, in which management comes to the forefront with objectives from the beginning to the end of the project, created a predictable positive effect on the value stream map. In the international applications of autonomous vehicle technologies, scientific approaches rather than competition, in which the global or regional introduction, the date of adaptation of the new specification or regulation and the definition are decisive, gave rise to interdisciplinary joint technology development teams in the field. National and international ministries of industry identify the countries where new autonomous vehicle technologies will be deployed: regional vehicle management, strategic project management and new technology adaptation expertise, the part that directs the newly added value flow to the process, provides value creation or preservation (CAN BUS connection systems etc.) and With the process participation of the responsible disciplines, the concepts of new design verification phase transition criteria, project criteria and scale were revealed. Therefore, the current lean product development process flow realized in GC companies, on the one hand, supports the protection of value and the introduction of existing customer expectations with new autonomous vehicle technologies, on the other hand, cross-relationship in the project flow, whose tests and analyses have been completed, with the regional vehicle management team and new technology adaptation department for value gain, it turns out that the functions that contain the data control the decision intersections (**Figure 11**). On the other hand, GC automotive manufacturing industry companies lead the feasibility negotiations of the main brand, affiliated to the central management, together with the strategic project management and product architecture expertise, and detailed comparison information under the scale of the project, in which the preservation of value regarding constraints, opportunities, needs or requests comes to the fore. It has been stated that the tolerances of acceptance criteria are discussed under possible scenarios in the approval of each stage transition in the lean product development flow of existing vehicle functions, which are important in value preservation together with the integrated approach in the introduction of 30 new autonomous vehicle functions defined during the field study (**Figure 11**). **Figure 11**, the value stream matrix shared by GC automotive company interviews, is given below.

In the light of the common information conveyed by the participants of GC companies, which have a more detailed value stream map and business processes compared to LC companies, the new project scale and investment budget, as well as the value creation and preservation, basic functions that are affected by innovations are envisaged at the beginning (**Figure 11**). In the new project plans with the aforementioned initial setup, the investment budget, the lean product development teams that will be activated, the hours of expertise, the strategic markets and market shares, together with the software and hardware, and all resources at the project entry level are defined (**Figure 11**). In GC automotive industry companies, the new project start time is revealed for the first time in the automotive design steps after the new autonomous vehicle technologies, the preparations for which have been completed, become applicable in the field (completion of R & D studies) according to the test and analysis results. The automotive design expertise phase (concept development), in which the requirements or physical needs of the new autonomous vehicle function are modelled at the initial level, emerges as the first step in which the new project objectives are transferred to the lean product development specializations. The new technology in the autonomous vehicle differs in form, embodies, automotive design and concept development initial stage, intensive design verification step-by-step studies are also planned, as well as confirmed under field observations.

Another factor that emerged in the lean product development flow updated under the value creation or preservation of GC automotive industry companies; Together with the determination of the project size level, the defined existence of the criteria that constitute the possibility of the new autonomous vehicle technology, which is in the initial stages of the process, to reach the applicable level and to be added to the vehicle (R & D researches are excluded from the scope of the study). In the research, the value flow in the lean product development process under the new autonomous technologies of GC automotive industry companies; with project levelling of the project mix and size, a pull system to be created for testing and analysis, step-by-step scheduling of all other interdisciplinary common stakeholders affected by the new autonomous technology piece with targeted function priority definitions, the process of determining design validation variables and tolerances can positively shift the process at the initial level. The said autonomous vehicle development initial approach; design verification phase transition approvals can orient autonomous vehicle project objectives. Therefore, in lean product development, the flow structure of function-oriented priorities and support units or expertise distributions of intersecting functions is revealed in a structure similar to the "First in First Out (FIFO-First in First Out)" system. Thus, the main effect on the functional link and priority structure between autonomous technologies, the continuity of the autonomous flow, and the transformation between the steps can be revealed under the value flow map. On the other hand, in the lean product development process carried out by GC companies under autonomous technologies, the determination of the stakeholders of the new function-oriented autonomous disciplines, which are among the main project objectives that constitute the testing steps between value preservation or creation, joint design verification step transitions (part-function-oriented algorithms, effects, probability calculations, variables and tolerances), reducing the diversity in testing and analysis and increasing the amount of use of the said knowledge within the company, it may be beneficial to keep the design transformation of the information on the autonomous part or the design speed at least at its current level. This approach can support GC automotive industry companies' controlled simplification in new vehicle adaptation of new autonomous technologies and components. The new autonomous vehicle technology disciplines that will join the lean product development disciplines are combined under the existing design activities, providing efficiency in the positive value stream. The new autonomous vehicle project sizes in LC automotive companies can be cascaded as in GC companies, and the establishment of the supermarket approach can define what size projects can be done, in how long, with how many employees and with what kinds of disciplines. At the same time, according to the autonomous level transitions that the lean product development team can intervene in, it can be defined in which region and when the autonomous technologies will be activated (according to the appropriate traffic infrastructure characteristics).

6. Discussion and Comparative Current

In two consecutive field studies of the research, the test and analysis conditions established by the participating companies for the new autonomous vehicle levels (from 0 to 5 autonomous commercial vehicle features and the 6th level) or the new product development that the critical technology parts carried out in external supply companies and traces of design collaborations were observed. Therefore, in the value acquisition or mapping under newly introduced lean product development criteria and parallel problem-solving techniques or new autonomous vehicle technologies structured on lean concepts such as chief designer, obea room, value stream, subject-specific in-depth, in-process common criteria and phase transition in metric scales variables are revealed. Collaboration structures that develop new autonomous technologies that are revealed in one-on-one meetings with GC automotive company managers within the scope of the fieldwork, or in the lean flow stages of new product development departments and specializations that form the basis of these structures; it includes new interdisciplinary transition conditions, existing or new software needs, new design transition conditions and hardware, new additional time and processes, result-oriented analysis values, holistic technical approaches under pairings, at the scale of value creation or preservation. In addition, the field studies of the research were carried out by considering the 3rd Level autonomous technologies on the new product in today's automotive industry applications.

While there are foresight plans regarding the design of 3rd level and 4th or 5th level autonomous vehicle technologies within the lean product development process in the automotive industry companies included in the field study, new software and hardware acquisitions for the adaptations of the advanced autonomous technology, research & development collaborations or new processes in the field during work with existing electronic parts supplier companies are among the study findings. All the information and findings revealed in the field study results of the research, that new autonomous technologies are adapted to lean product development processes with an inductive approach within the current value stream and that innovations are gradually created at increasing positive values based on vehicle speed/time (newly involved in lean product development and design stages, autonomous technology applications) have been determined specifically for GC automotive companies. The basic approach of the company managers in the field study: the adaptation of new autonomous technologies to existing lean product development processes or the re-modelling and mapping of the current value stream, the articulation of innovations under existing lean concepts in company-specific applications in the automotive sector, where there is heavy competition, have important results.

7. Conclusion and Evaluations

Competition in today's automotive industry, where the physical and virtual communication boundaries have been lifted and global brand mergers have become common, especially in the product development and manufacturing industry, is spreading in the design and application of autonomous vehicle technologies. With the use of personal and vehicle safety technologies in autonomous vehicles in the near future, it seems that the substitution of driverless vehicles will increase, as they become sufficiently safe [39]. Today, the new product development process created by the innovation-oriented competition approach has turned towards the efficiency of the value creation and preservation flow under the concept of simplification. Automotive industry products, where global competition comes to life in local regions, are differentiated by joint working groups of different companies or new company establishments over brands under autonomous technologies. The autonomous technologies developed in these structures will result in the emergence of a large number of by-products and secondary products, which will bring about significant changes in the manufacturing industry and service sector [40]. Autonomous vehicle technologies, including environmental factors and regional differences, cannot be internalized by automotive manufacturing industry companies due to the uncertainty of legal responsibilities.

Autonomous vehicle technologies, with increasing competition and intense new product development activities observed in the companies included in the research, are mainly procured from foreign supply channels. The supply of autonomous vehicle technology parts through outsourcing channels has led to the formation of new disciplines in lean product development and project studies, as well as new software or applications. New expertise such as intelligent systems (IoT) and connected systems user experience, energy management digital motor chassis or digital powertrain decision-making software have been included in the lean product development disciplines in the automotive manufacturing industry with their physical and virtual functions testing and analysis. Engaging with autonomous vehicles; new technologies such as Lidar, Lane, GPS, Radar, Ultrasonic, Stereo Vision, Infrared Camera, Wheel Encoder, MC Main Computer, etc. have made interdisciplinary studies more complex in the lean product development process. In addition, new autonomous vehicle technologies such as: Vehicle Network System Communication, Steering and Actuary Electronics, Autonomous Routing, Vehicle Electronic Safety, Interior & Exterior Vehicle IoT, Interface Control, etc., and similar new disciplines have been included in lean product development processes. The disciplines that are newly involved in the lean product development flow realized in the automotive industry companies that are involved in the fieldwork, are gradually put into use by measuring the value creation or preservation in the process. Another finding determined in the results of the research is that with the positive effect of new autonomous vehicle technology development centers or partnerships of global automotive industry companies, vehicle adaptation studies are implemented in a more controlled manner. In addition, vehicle adaptations of new autonomous technologies developed under the partnership of global automotive industry companies are configured in certain vehicles and in a certain code system. Therefore, the new technology designed according to the vehicle shows high compatibility and finds solutions more easily in the definitions of possible problems. On the other hand, technologies such as digital intelligent guidance systems or vehicle mass transfer and precision steering create different connection possibilities with other autonomous vehicles within the same sensitivity in order to enable features that are still not seen today or to make better use of the infrastructure [41]. In addition, various usage scenarios created by autonomous vehicle technologies enable remarkable developments and changes on the vehicle interior and exterior structure or on the intelligent design of vehicle-human machine interaction. A comparison study focused on creating or maintaining innovation in the value stream of similarities and differences in company-level applications of new autonomous vehicle technologies with global GC and local LC automotive manufacturing industry employees, and its micro-level results are gradually shared.

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Conflicts of Interest

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

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