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METHODOLOGY FOR REQUIREMENTS AND SYSTEM DESIGN FOR THE DETECTION OF DANGEROUS DRIVING

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Abstract. *An ever-increasing demand for mobility ends up increasing life risks to vehicle occupants and pedestrians, so there is a need to monitor driving behaviour. In this context, the aim of this paper is to demonstrate the methodology in use for the synthesis of requirements and architecture of a system with the purpose of monitoring driving behaviour towards dangerous driving. While currently available vehicle dynamics control systems involve the necessary sensing resources, there is still a need to recognize driving hazards and thus improve the ability to mitigate them. The development methodology begins with approaching the driving task context and the vehicle-driver interfaces, and proceeds with verifying the postures, attitudes, and respective parameters in monitoring areas, towards the definition of requirements and architecture for assessing driving behaviour. With the problem of detecting dangerous driving in mind, the proposed system is intended for monitoring behaviors with potential contributions to the occurrence of traffic hazards, thus establishing use cases for vehicle safety systems. Such system definitions establish design foundations to configure sensory matrices aiming at the improvement of vehicle safety, with capabilities to detect and measure hazardous driving behaviour.*

Keywords:

Systems and requirements engineering, Design methodology, Vehicle dynamics, Vehicle safety, Dangerous driving.

1. INTRODUCTION

The lack of traffic safety has caused significant damage to society; besides the loss of lives, financial costs due to the operation of traffic rescue and health emergency services which fail to preserve lives due to the severity of the traffic occurrences. According to Garner *et al.* (2003), traffic accidents in the 49 Brazilian urban agglomerations resulted in costs of approximately R\$3.6 billion in 2001 (price basis from April 2003). When considering the whole urban area in the country, these costs reach R\$5.3 billion, including 62% of the nationwide vehicle fleet.

In Brazil, traffic accidents result in approximately 45.000 fatalities and cause severe injuries to more than 300.000 people per year. As a consequence, the financial costs linked to those lives lost, the severely injured, and other losses accumulate to around R\$40 billion per year from highway traffic, and around R\$10 billion from densely populated urban areas. Significant parts of those result from material, logistics, opportunity and transaction costs, alongside the costs with traffic rescue and emergency health services. Yearly statistics for 2022 reached 64.447 occurrences, of which 52.948 incidents involved severe injuries or fatalities (CNT, 2022). The major cause of accidents is the human factor. Thus, dangerous drive behavior remains a key issue. Recognizing dangerous driving styles using patterns (Evans and Wasielewski (1983); Shahverdy *et al.* (2020)) and issuing alerts can be an effective strategy to improve traffic safety, according to the Brazilian traffic legislation (Government of Brazil, 1997).

Therefore, the objective of this work is to demonstrate a design process based on systems engineering, and respective results, for the development of an event detection system with regard to the problem of dangerous driving. For this task, we use sensors already present in the vehicle to identify the use cases determined based on research.

This article is organized in a literature review, addressing concepts related to systems engineering and dangerous driving, followed by the proposed methodology used by the approach for system development. Finally, the conclusion of the project is presented and discussed.

1.1 Driving assistance systems

In response to such examples, manufacturers have been putting significant effort into implementing active safety measures on passenger and commercial vehicles. Systems implementing these measures are also known as Advanced Driver Assistance Systems (ADASs), comprising a variety of embedded electronic systems designed with the intent of supporting the driver through demanding traffic situations. These systems are supposed to collect information from the vehicle and around it in order to engage supportive control measures to the dynamic behaviour of the vehicle; by providing partial driving automation under certain situations on which they take control of the vehicle, they enable improvements to energy efficiency and driving safety (Lindgren *et al.*, 2008).

Regarding the sensory scope of ADAS, Bengler *et al.* (2014) make a useful distinction between: (i) proprioceptive sensors that monitor dynamic parameters from in-vehicle components and systems such as acceleration, braking steering, doors and seat belts; and (ii) exteroceptive sensors that perform surveillance over the outer traffic environment including other vehicles, obstacles, pedestrians and road conditions. This distinction influences the design of ADAS regarding their coverage about communication and control inside and out of the vehicle, including the fusion of several data streams to enable the proper engagement of driving assistance control measures (Bengler *et al.*, 2014).

Available ADAS support the driving task with functionalities that include warning alerts, automated takeovers, and the automation of specific driving tasks; sensory information is processed for providing auxiliary or supervised dynamic control. Examples include: Lane Departure Warning System (LDWS); Lane Keeping Assist (LKA); automated emergency brake (AEB); Adaptive Cruise Control (ACC); and, Blind Spot Detection (BSD), among other systems (Ziebinski *et al.*, 2017). However, the most important factor to the effectiveness of ADAS systems is the vehicle-driver interface, and how it can work so that drivers understand how these systems help their driving experience (Saffarian *et al.*, 2012)

1.2 Driver behaviour

The World Health Organization (2018) reported the main causes of traffic accidents with including speeding, Driving Under Influence (DUI) of alcohol or drugs and driving distraction, with recommending the enactment of stricter and more rigorous laws along with effective traffic law enforcement, safer highway and street driving infrastructure and permanent education campaigns to mitigate those risks. The NHTSA reports about the effect of mobile phones to inducing driver distraction, which impairs the traffic awareness of the driver with slower reaction time and increased collision risk. Nevertheless, traffic experts agree that the biggest problem that must be overcome is that of driver behavior.

For instance, Dula *et al.* (2010) investigated the impact of anxiety on driver behavior, to find on the influence from psychological stress towards driving behavior. They found higher clear link between higher levels of anxiety and dangerous driving behaviour. High-anxiety drivers score significantly higher in regard to seat belt citations, cutting off other vehicles and higher about at-fault crashes and tailgating, which mean taking significantly higher risks in traffic and increasing the probability that accidents may occur. Another finding is the role of anxiety in reducing the cognitive capacity of drivers, which impairs their ability to pay attention to other drivers moving around or even to obstacles.

Lindgren *et al.* (2008) reported cultural differences towards traffic rules and safety between different countries, establishing a relationship between the tolerance to rule-breaking and the aggressive and dangerous driving behavior. The cultural factor could be linked to driving behaviors such as overtaking on both sides, lane-changing between the traffic and the emergency lanes, driving by the emergency lane to get through traffic, and cutting off others. This involves the perception of ADAS (Advanced Driver Assistance Systems) by drivers, of which the distance setup of the ACC is an example: some drivers may find it positions the car with too long a headway to the next vehicle.

2. LITERATURE REVIEW

2.1 Factors to ADAS effectiveness

The availability of information providing input for in-vehicle warnings and controls is a significant factor determining the feasibility of implementing these systems. Lane-keeping systems and speed control warnings may depend on key infrastructure resources such as navigation systems and signalling infrastructure. Inconsistencies in these resources such as unclear/unrecognizable signalling and wrong speed limit information from navigation systems impair system reliability and hamper driver confidence in their functionality. As a consequence, drivers and even manufacturers may turn off selected ADAS features for selected markets depending on infrastructure conditions (Lu *et al.*, 2005).

The effectiveness of ADAS in improving vehicle safety has a direct link to their acceptance by drivers. This is significantly influenced by cultural differences, which may require manufacturers to set up ADAS differently in regard to driving customs in individual markets. Depending on the adherence of the driver to traffic rules and his tolerance to risk, a system that works well and reminds the driver when needed in a certain place may be regarded as too intrusive and perceived as a nuisance in other places. However, there is need to find a balance between adherence to rules and flexibility to drivers' attitudes, to avoid reinforcing bad traffic habits where they exist (Lindgren *et al.*, 2008)

The development of those systems evolved from modulating the vehicle behavior in limit situations to performing actual driving controls as delegated by the driver. The driver becomes more engaged with supervising the driving task performed by onboard systems than with actually controlling the vehicle, which may lead to over-reliance on automated systems and reduction of situation awareness by the driver, under which warnings may not be rightly understood or certain control actions could be regarded as 'automation surprises' alarming/annoying the driver. Therefore, keeping a minimum degree of engagement by the driver is critical for ensuring their safety (Saffarian *et al.*, 2012).

2.2 About design processes and systems engineering

The design process is a systematic approach to developing a complex system.

Systems Engineering is a multidisciplinary approach that suggests guidelines for the design of complex systems (Forsberg and Mooz, 1991). This design approach encompasses the design process in a detailed progression from requirements analysis, and an integration progression from detailed components to implementation and management of the system throughout the life cycle. The discipline deals with the analysis of the needs and requirements of a system, developing models, simulation, component integration, verification and validation planning, implementation and product management (INCOSE, 2023). In summary, Systems Engineering aims to effectively and efficiently develop a system, ensuring that stakeholder and user demands are met, integrating components properly, and performing verification and validation to ensure correct functioning.

The model proposed by Shishko *et al.* (1995) covers highlights for the elaboration of a project in a systematic and duly organized way, following the phases of stakeholder expectation definition, technical requirements definition, logical decomposition and design solution definition, in order to guarantee the compliance with established design requirements. Initially, in order to gather the existing expectations about the project, it is necessary to identify the system's stakeholders, which may include individuals or groups affected by the product, such as customers, companies and government agencies. Next, it is necessary to understand the expectations of the stakeholders, this being one of the most important steps in the project, ensuring that all parties agree with the characteristics of the system and that it is designed in the most appropriate way possible (Shishko *et al.*, 1995).

The process continues with the identification of Needs, Goals and objectives (NGOs). Needs point out a problem that must be solved, but without indicating a possible solution. Goals deal with the elaboration of needs, in order to bring a series of expectations to the system. Objectives are linked to goals, presenting a specific level for them. Next, the CONcept of OPeration (CONOPS) and the Measures Of Effectiveness (MOEs) are established. The process begins with the definition of requirements, which are divided in two ways: functional requirements and performance requirements. Functional requirements, which, based on the objectives already chosen, define functions that the system must have. And, performance requirements, which define how well the functions must be fulfilled (Shishko *et al.*, 1995). Finally, these requirements are validated to check writing, technical level, relationship with stakeholder expectations, feasibility, if the requirements are verifiable, and ambiguities.

2.3 External influencing factors

It is necessary to consider external factors to define preventive provisions about reliability and robustness, according to Song *et al.* (2012). Dust is a new factor in describing the operating conditions of electronics, in addition to temperature and relative humidity. The impact of dust on electronics reliability is increasing due to miniaturization of technology and shrinking trace spacing on Printed Circuit Boards (PCB's) and between components. Dust particles can cause electrical leaks, short circuits and open PCBs under various conditions (Song *et al.*, 2012).

As seen by Deutschmann *et al.* (2018), electromagnetic interference has an effect on the internal electrical components of a modern vehicle, and power smart devices, increasingly present in automotive systems. These control vehicle systems such as ABS and protective airbags. The crucial issue of this interference is the exposure of electronic devices to adverse environmental conditions, such as extreme temperatures and mechanical stress (Deutschmann *et al.*, 2018).

Abdi and Benjemâa (2014) noted that the wear of connectors that suffered vibrations depended on several conditions, such as temperature, acceleration and frequency of vibration. Therefore, as analyzed, these factors can contribute to the wear and tear of the electrical components present in the vehicle, causing wear or any other harmful failure for the system as a whole (Abdi and Benjemâa, 2014).

According to Almubarak (2017), the causes of overheating and its effects on decreasing the efficiency of different types of electroelectronic devices include variation in environmental temperature, humidity and even human error such as storing the devices in aggressive or degrading environments. Thus, the degradation of the material present in the system occurs, with expansion and deformation of the structure and even reaching the point of crack formation, component failure and the worrying risk of fire (Almubarak, 2017).

2.4 Requirements from operational needs to architecture

Grady (2010) defined requirements as an attribute of considerable importance for a system and characterizes its writing as a statement that has sentences structured and organized in an appropriate way, following a pattern of indication keywords, which can be numeric or non-numeric. An important tool in requirements engineering is its link with its source, the so-called traceability. It has the function of linking parent and child requirements, in order to later indicate the importance for the design of a system of a specification made at the beginning of the program. In addition, they also help answer why a specific requirement was identified (Grady, 2010).

It can be performed vertically - from a parent to child requirement; longitudinally - from a former revision to a latter revision of the requirement; or laterally - between different requirements at the same level. Sikora *et al.* (2012) presented the need to specify the system requirements according to the variation of the design abstraction level, which is directly intertwined with the system architecture, resulting in a dependency between them. In this way, the requirements are established to satisfy a specific object to be developed (Sikora *et al.*, 2012).

The system architecture, in turn, deals with the object itself, with its interfaces between the present subsystems. Meanwhile, the level of abstraction of a requirement changes according to the type of object and its position in the architecture. These levels work as the context for performing the logical decomposition as the system development proceeds in defining increasing level of detail to requirements, guidelines and solution specifications. This process consists of the steps of translating high-level requirements into functions responsible for satisfying them, allocating functions to lower levels of the system, and identifying necessary interfaces and subsystems (Alexander *et al.*, 2016).

2.5 Design solution

Taking into account the previous processes, the design solution uses high-level system requirements in conjunction with logical decomposition to obtain a design solution. The process description encompasses receiving the inputs from the previous topics (technical requirements and logical decomposition), defining and creating initial alternatives to solve the problem, then analyzing all the developed possibilities, checking requirements, performance measures and other selection criteria, and finally, choose, fully describe, verify, validate, identify enabling products, and baseline the design solution (Alexander *et al.*, 2016). Here, system models play an important role in the automotive industry in ensuring vehicle safety.

Models represent, through abstract descriptions, the system to be developed, taking into account the present components, in order to enable analyzes and simulations to guarantee the reliability and robustness of the product. Within such analyses, reliability is an important concept to be considered throughout the whole vehicle system. While there is consolidated reliability-related design practice in mechanical systems design, there is need for attention regarding embedded systems.

It is in this context that the ISO 26262 Standard refers to functional safety as the ability of an automotive system to function safely over all circumstances, either by fully operating to design specifications, or by entering degraded operating regimes with preserving controllability and safety of vehicle and driver (ISO, 2018). Satisfying these criteria requires analysing the risk about failure modes associated to the system. In addition, secure development, maintenance and continuous monitoring, and adequate management of changes made during the project's life cycle must be ensured.

On the other hand, robustness is a fundamental requirement for the safety of intended functionality as defined by the ISO 21448 standard (ISO, 2022). The concept about *safety of intended functionality* regard the ability a driving assistance system has in complying with operating requirements even under adverse conditions (Marini *et al.*, 2021) with external disturbances and noise hampering the ability of certain vehicle system to operate properly while riding.

To ensure this feature is to be achieved, a vehicle system development team shall pay attention to the following aspects: i) system architecture shall provide for alternate working paths under which certain functionality can still work; ii) edge devices need to be specified about keeping their functionality under aggressive/harsh conditions. Verification and validation of the product shall include test protocols where these disturbances are considered, to document the ability of driving systems to operate (ISO, 2022).

3. METHODOLOGY

The methodology for performing the early design stages of a driving assistance system to detect dangerous driving comprises activities which prescribe the context under which the system operates, the needs of the parties involved in the systems life cycle, the parameters on which the systems quality is measured, the function transformations executed by the system, and the architecture on which the system is implemented.

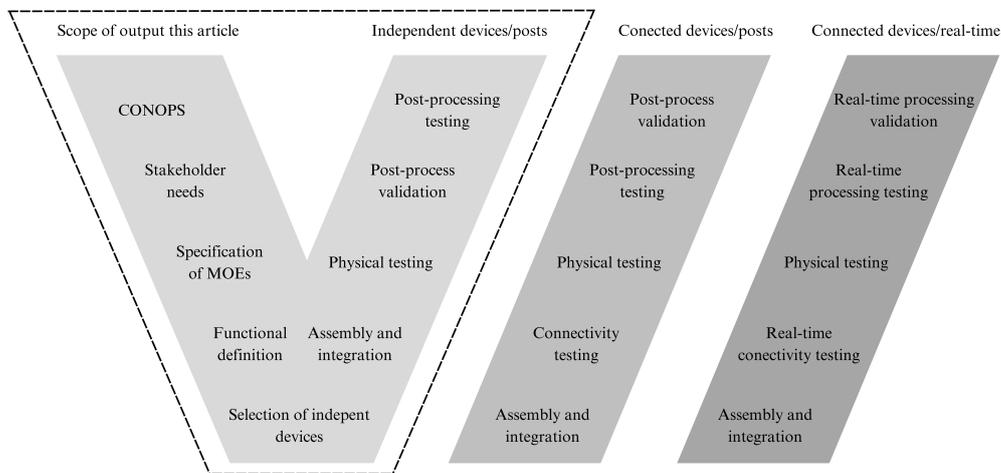


Figure 1. Vee diagram of project.

This system design work is performed on the scope of intended functionality for the system, including its interfaces with the vehicle, the driving task scenario and the prototype assembly with physical testing on a scale vehicle platform. Figure 1 presents the methodology used for the development of this project, which was built based on the Vee diagram model (Alexander *et al.*, 2016). The dash-lined frame around the 'V' indicates the part of the systems engineering process executed in the scope of this paper.

3.1 Analysis of stakeholder requirements

The methodology used to carry out the stakeholder analysis was based on a broad and systematic approach (Alexander *et al.*, 2016). The identification of the actors involved in the system was carried out based on research and a review of the bibliography. In addition, in order to capture the expectations of stakeholders, a comprehensive description was sought, avoiding conflicts between verified needs. Possible interest groups were mapped, such as end customers, communities and regulatory bodies. Finally, the results were documented in a spreadsheet subject to future changes and allocations with the requirements.

The main stakeholders of the system were identified: (i) Drivers, (iii) Vehicle manufacturers, (ii) Insurers, and (iv) Traffic authorities. It is worth mentioning that the number of existing stakeholders exceeds those mentioned, enabling the possibility of updates in future system extensions considering the parallel integration processes to be carried out in further process iterations. Requirement statements at this stage are intended to set the expectations on how the system performs on stakeholders' perspective. Therefore, these are stated using modal verbs (shall, must), which is a standard-recognized language and also mentioned as part of the so-called informational design (Fonseca, 2000).

Must-statements usually derive from legal statements and technical standards, which requires monitoring of legal and technical developments related to intended system functionality. **Shall**-statements require monitoring by the technical team to make stakeholders aware of the functionality under development and its performance, thereby enabling negotiation of requirements.

Stakeholders' requirements are presented in Tab 1.

Table 1. Stakeholders and their requirements.

Stakeholders	Requirements (The system...)
Drivers	<i>Shall</i> alert the driver about behaviors that are identified as dangerous, such as sudden braking, excessive speed, sudden lane change.
	<i>Shall</i> provide feedback in a clear and direct manner, so that the driver corrects his attitude in traffic.
	<i>Shall</i> accurately and reliably label the driving attitudes with basis on onboard dynamic detection.
	<i>Must</i> no cause unnecessary distractions to the driver.
Manufacturers	<i>Shall</i> use components that can be easily integrated to the vehicle architecture, commercially available or present in current vehicles.
	<i>Shall</i> have low impact on battery consumption or vehicle performance.
	<i>Must</i> comply with vehicle and traffic safety regulations, applied globally and in the country.
Insurers	<i>Should</i> help reduce the number of road accidents.
	<i>Must</i> reduce the resulting damages from accidents still occurring.
	<i>Shall</i> produce accurate data on the behavior profile of users.
Traffic authorities	<i>Must</i> comply with global data security standards.
	<i>Must</i> store data on dangerous driving behavior for accident investigations.
	<i>Shall</i> collect statistical data on driver behavior for trend analysis.
	<i>Should</i> contribute to awareness of traffic laws and limits on driving practices.

3.2 Concept of operations (CONOPS)

Initially, based on the analysis of expectations and needs of the listed stakeholders, preliminary scenarios of situations in which the system should act were defined. The concept of operations is intended for describing the contexts and circumstances under which the system is intended to work, about recognizing driver behavior that creates hazard to the traffic environment, other vehicles and pedestrians.

During development, internal workshops were held with team members in order to review and refine the defined scenarios. Based on this, it was possible to list interfaces, functionalities and measures of effectiveness, in order to clearly describe the concept of system operations and its use cases. In the scope of this work, three scenarios are considered as dangerous driving, as depicted in Fig 2: (i) the brake checks, (ii) the sharp curves, and (iii) the traffic with speed above the allowed by the road.

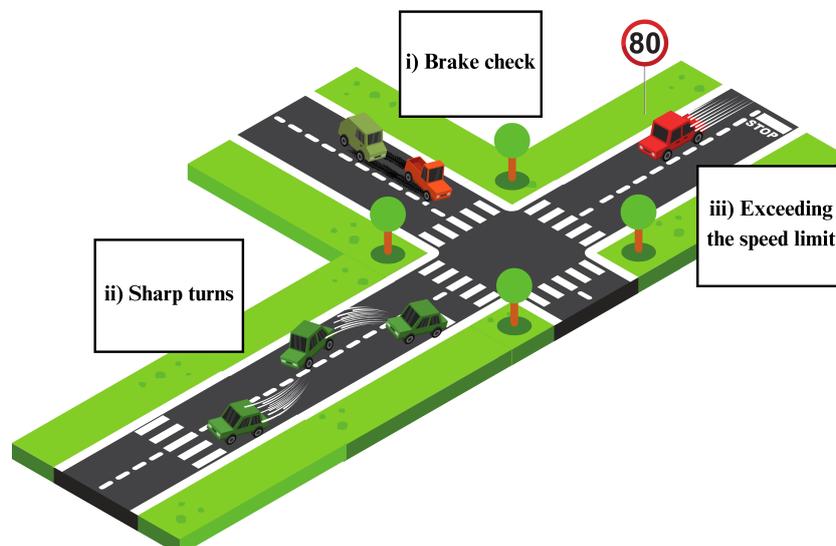


Figure 2. Operating scenarios to detect dangerous driving.

The system for detecting dangerous driving is intended to recognize driver behaviour a variety of scenarios whose representation is intended to convey the driving tasks on which it is supposed to help the driver to engage actions to position. Figure 3 depicts the system basic operation obtained with the development of CONOPS in the scope of this work. CONOPS provided an expanded view of the system’s operation, bringing a description of the product’s functions and requirements.

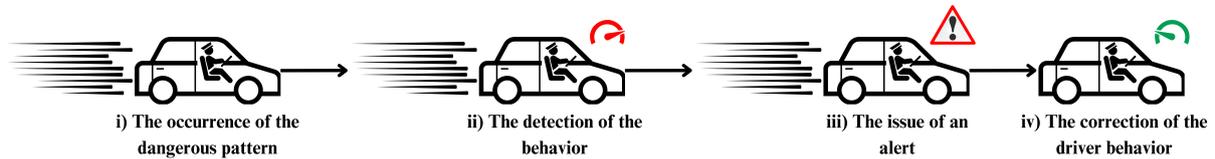


Figure 3. Basic system operation.

Thus, the basic operation of the system must include the following functionality: (i) the occurrence of the dangerous pattern, (ii) the detection of the behavior, (iii) the issue of an alert and (iv) the correction of the driver behavior. The project team is engaged in developing the enabling part to ensure complete functionality is achieved, namely the steps i) and ii) about detecting dangerous driving behavior. Establishing the CONOPS provides an overview about the cases under which the system shall work and the method of its fulfilling the intended functionality.

Hence, the context of operations provides guidance regarding the development of the dynamic functionality, which enables further analysis about trade-offs and outright conflicts between applicable stakeholders’ requirements, thereby allowing for the discussion and the clarification of development guidelines about the detection of dangerous driving.

3.3 Measures Of effectiveness (MOEs)

The discussions carried out by the team generated adjustments and revisions in the preliminarily defined measures of effectiveness. To compute the effectiveness of the system, the project team engaged into defining a set of performance indicators that describe the acceptable functionality the system shall achieve. To define the Measures Of Effectiveness (MOEs), the KPIs of the system project were listed, based on the defined stakeholders and internal team meetings. The performance indicators and their required minimum values are described in Tab 2.

Table 2. Design specification on Measures of Effectiveness

KPI	Value	Measuring method
Dangerous behavior detection rate	> 90%	Live driving inspection
Rate of relevant alerts	> 75%	
False positive rate	< 4%	
False negative rate	< 8%	
Behavior correction rate	> 65%	
Sampling rate per distance traveled	> 5 m ⁻¹	System testing
Maximum current of the aggregate system	< 5 A	
Driving sample time length	= 15 s	
Driving acceleration triggers	TBD	Driving sensor log
Driving turning rate triggers	TBD	
System response time	< 0.1 s	
Shortest time to collision, longitudinal	> 1 s	
Shortest time to collision, lateral	> 0.5 s	
User adherence	> 90%	Operation statistics
Reduction in the number of road accidents	> 15%	
Reduction of material damage	> 40%	
Reduction of traffic violations involving dangerous driving	> 30%	

The measures of effectiveness based on frequency rates shall be inspected with the system installed on a vehicle to monitor the driving behavior (Live driving inspection); the measures linked to component specification and capability shall be assessed with system testing, which can be performed separately or within a vehicle (system testing); the measures linked to the event triggers on dangerous driving shall be defined with developing and further refining the driving detection algorithm; the parameters linked to detection timing (system response) and dynamic timing (time do collision) shall be monitored and evaluated with a driving sensor log; and, the end results of the system performance shall be measured by fleet operation statistics.

To measure the degree of success of the product, the preliminary MOEs were identified based on their relevance, technical feasibility and measurability, in order to promote the monitoring of the quality and performance of the system. This specification is intended with focus on the dangerous driving detection, therefore the following measuring methods were established in first place: Using what is described in this table, it is possible to quantify and monitor the success of the system during the project and after its introduction in the market, making constant the evaluation of the quality and effectiveness of the developed product.

3.4 Functional structure

Initially, for the development of the functional structure, or Functional Flow Blocks Diagram (FFBD) (Alexander *et al.*, 2016). The main desired functions of the system were identified: (i) collect vehicle data and (iii) the issue of an alert. Then, the functions were decomposed into smaller blocks based on the requirements table, and were linked to their related inputs and outputs, implying a dependency relationship between them as shown in Fig 4.

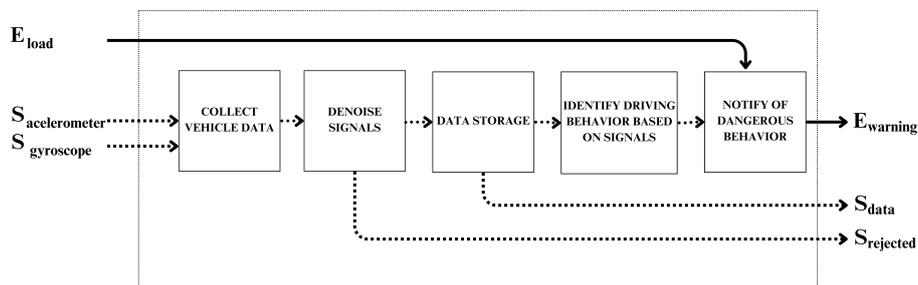


Figure 4. Functional flow block diagrams (FFBD).

Being S signal, E energy, load relative to electrical energy, accelerometer and gyroscope the sensors used, data stored information, and reject noise rejected from the sensor signal. From this, it was possible to carry out a clear identification of the system’s functionalities, making visible the dependencies and interactions necessary for the system project, helping to obtain a basis for the development and decision making in the project.

3.5 System’s architecture

Initially, the needs and constraints of the system to be considered for the construction of the architecture were identified. Based on CONOPS and allocated requirements, the system components and their necessary interfaces were defined. From a block diagram model, a preliminary model of architecture was defined, making it possible to visualize the high-level structure of the system. Figure 5 depicts the system’s architecture.

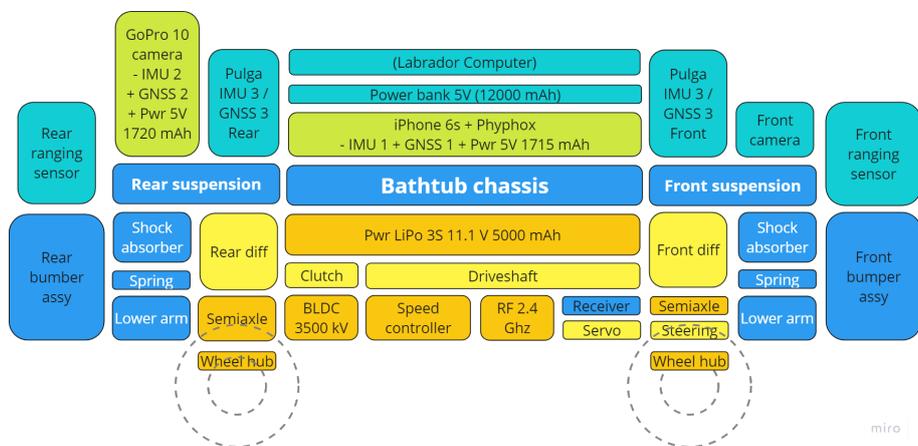


Figure 5. System’s architecture over 1/10 RC model.

The diagram in Fig 5 was used for an evaluation made through prototyping the system, ensuring its proper functioning and robustness, and indicating the need for updates and addition of components.

3.6 Prototype assembly

During the implementation phase on the Traxxas prototype, two key pieces were employed for preliminary sensing, providing a solid foundation for capturing images and inertial and location data. The GoPro 10 Black was chosen for its high-resolution imaging capability and integrated Inertial Measurement Unit (IMU) and Global Navigation Satellite System (GNSS) suite (see Fig 6(a)). The camera was attached to the vehicle's fairing with an adhesive backing, ensuring a stable, unobstructed view of the environment.



Figure 6. Assembly of the prototype for the remote-controlled vehicle used in the data acquisition process.

In parallel, an iPhone 6s fixed in a speaker frame under the fairing of the vehicle (see Fig 6(b)). The iPhone 6s was used to complement the inertial and location data. The combination of these devices not only provided an expanded view of the driving environment, but also allowed an overlay of inertial and location data for a calibration of the obtained data.

These characteristics are key to identifying dangerous driving behaviors and represent significant steps towards the ultimate goal of increasing vehicle safety. The prototype architecture demonstrated effectiveness and potential for future improvements, including the addition of a Power Bank to increase the autonomy of data captures through the iPhone 6s, in addition there is the possibility of implementing a Single Board Computer, to expand the possibilities of captures.

3.7 Project activities

Periodic review meetings were held between the team, verifying the technical feasibility, impact and relevance for the project. The project activities includes monitoring and reviewing the stated requirements, regarding questions such as the following: (a) can the requirement be complied with? (b) shall the requirement be further specified? (c) are there other requirements that need attention of the project? (d) can the requirement be re-specified to improve stakeholder adherence? (e) do stakeholders allow dismissing the requirement? Thus, this process allows to obtain a solid basis for decision-making, facilitating communication and alignment of stakeholders.

4. CONCLUSION

In conclusion, it can be stated that the systems engineering approach provided a structured and systematic application of the design methodology. The concept of operations allowed the team to have a clear and comprehensive view of the required functionality. The stakeholder analysis is a useful tool to provide the listing of the main interested parties in the project, and the MOEs brought the possibility of an objective and numerical evaluation for the system to reach the desired performance. The making of the architecture provided an effective integration of the components, taking into account the interfaces. From there, the FFBD helped to identify and implement the functionalities required by the system. Finally, with the construction of the preliminary prototype, it was possible to validate the functional viability of the system, and make necessary adjustments and test the model.

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