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Designing a service for the future of the truck platooning ecosystem

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Master Dissertation

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"A goal without a plan is just a wish."

Larry Elder

Abstract

Over the last few decades, automated vehicles (AV) sector have made significant advances, fuelled by an enormous potential to continue changing the transportation business. The world's population is increasing on a regular basis, indicating a constant increment and pressure on global demand for products. Digital commerce is now an easy and open store for humankind. Therefore, new challenges for transportation are on the way, and new technical solutions are the subject of study and implementation throughout the world. One of the most promising innovations is truck platooning technology, an approach that enables the connection of two or more heavy vehicles moving in close formation and through a semi-automated way.

This dissertation examines the implications and constraints of automated driving technology, with a specific emphasis on truck platooning in the freight transportation industry. The framework of the continuing TRAIN project investigates how logistics businesses, truck drivers, and facilitators, specifically road operators and regulators, play critical roles in influencing the future of vehicle automation.

This study begins with an extensive literature analysis to identify relevant concepts, data, and worldwide perspectives on truck platooning, and after that a qualitative approach including face-to-face interviews was conducted to collect information to better understand crucial technological components to assist the creation of some design service artifacts for the development of a conceptual digital platform, where stakeholders can share resources and split costs during daily operations.

While the TRAIN project supported this research, this thesis did not actively engage in it, instead it focuses on service platforms from the perspective of logistics organizations, specially how they perceive and expect to adopt their operations regarding a future conceptual design of a digital platform service provider.

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List of Abbreviations

ACC – Adaptive Cruise Control.

ADAS – Advanced Driver Assistance Systems.

APM – Arnold Peter Moller - Maersk Group.

AV – Automated Vehicles.

AWS – Amazon Web Services.

BMC – Business Model Canvas.

BPM – Business Process Modeling.

BPMN – Business Process Modeling and Notation.

CACC – Cooperative Adaptive Cruise Control.

DB – Database.

DSR – Design Science Research.

DSRC – Dedicated Short Range Communications.

ENSEMBLE – Enabling safe Multi-Brand platooning for Europe.

EU – European Union.

EU TPC – European Truck Platooning Challenge.

ENSEMBLE – Enabling Safe Multi-Brand Platooning for Europe.

FEUP – Faculty of Engineering - University of Porto.

GDP – Gross Domestic Product.

GPS – Global Position Systems.

HTTP – Hypertext Transfer Protocol.

IEEE – Institute of Electrical and Electronics Engineers.

IS – Information System.

IoT – The Internet of Things.

ITS – Intelligent Transportation System.

MESG – Master's in Services Engineering and Management.

PAF – Platooning Autonomous Function.

PSF – Platooning Support Function.

SAE – The Society of Automotive Engineers.

SC – Supply Chain.

SOA – Service-Oriented Architecture.

TP – Truck Platooning.

UML – Unified Modelling Language.

V2I – Vehicle-to-Infrastructure.

V2V – Vehicle-to-Vehicle.

VPN – Virtual Private Network.

1 Introduction

As the digital revolution continues to disrupt our daily lives, integrating automated technology into supply chains (SC) is no longer simply a possibility, but a critical success factor for all businesses (Hofmann et al., 2019). Because AV promised to rewrite the core of existing logistical techniques and bring in a new era of possibilities, the industry was attracted by its development (Hakak et al., 2023). The majority of companies acting in the transportation sector worldwide need to investigate the capabilities of this automation in order to achieve long-term sustainability, efficiency, and safety (Dekhne et al., 2019).

According to EUROSTAT's estimation in 2021, the volume of every type of freight transportation represents a substantial 105.5(%), of the GDP across all EU member states. This suggests that the demand for transported goods is remarkably high compared to the size of the economy. As a result, every EU member has a high reliance on imports and exports as key contributors to GDP growth.

Each mode of goods transportation has distinct characteristics and impacts, covering various choices such as road, rail, air, inland waterway or maritime. When considering any type, they may differ in expenses, time costs and service performance (Kiani Mavi et al., 2022). The predominant mode of freight transportation is commonly by road, primarily due to notable advantages related to greater flexibility, efficiency, and reliability (Callefi et al., 2022). For those reasons and more, one of the unique projects in road freight transportation has been the truck platooning (TP) model, facilitated by advanced technologies, in different levels of automation, and communicating vehicle-to-vehicle (Jacob et al., 2018).

This work was conducted at the Faculty of Engineering - University of Porto (FEUP), within the scope of the Dissertation from the Master's in Services Engineering and Management, focused on promoting and creating new conceptual service for the future of the truck platooning ecosystem.

1.1. Context

Truck platooning has emerged as a revolutionary approach, within a concept from the Intelligent Transportation Systems (ITS) framework, to transform the core of road freight transport. Numerous initiatives, research projects and studies, led by the European Union (EU) governments and industries are committed to exploring this new model (Solberg, A. 2022, Schirrer et al., 2022). Nevertheless, what precisely does TP mean?

As shown in Figure 1.1., TP is an innovative driving approach, where a group of two or more heavy vehicles travels together, guided by advanced driving automation technologies in which the leader sets the pace, and the others automatically follow staying coordinated at a close distance from each other (Schirrer et al., 2022).

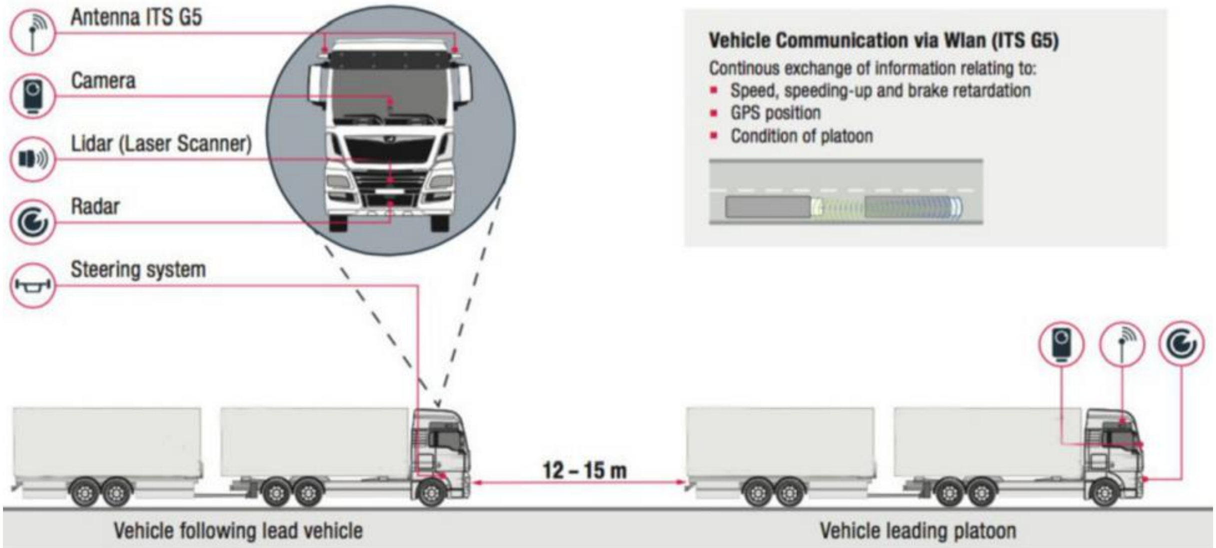


Figure 1.1: Platooning Technologies - From: Balador et al., (2022).

The Cooperative Adaptive Cruise Control (CACC) is the technology that supports communication between vehicles and infrastructure through the use of bilateral wireless sensors including radars, cameras, and antennas. It is based on the concepts of Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I). This allows for the real-time sharing of indicators such as position and speed (Janssen et al., 2015, Balador et al., 2022). However, truck drivers are still responsible for monitoring the surrounding roads and traffic due to a slight difference in the automation levels of CACC and TP (Shladover et al., 2018).

Different levels of automation were defined in accordance with the Society of Automotive Engineers (2021), in order to distinguish and make clear the roles that machines and humans play in different contexts. Consequently, a scale for grading these levels is provided by the SAE J3016 framework (Appendix A), with 0 representing no driving automation and 5 indicating complete automation. According to Calvert et al., (2019), the current state of TP is usually in levels 1 or 2, where drivers are still actively involved in some aspects of vehicle control. Hence, the ENSEMBLE project highlighted two different kinds of platooning functions and provided a fresh background. The first is the Platooning Support Function (PSF), in which the driver controls longitudinal aspects, while the second is the Platooning Autonomous Function (PAF), where the system is responsible for both longitudinal and lateral controls (Mascalchi et al., 2020). ENSEMBLE explored one of the most significant challenges of TP, which was having truck companies from different brands planning and sharing information in normal daily operations. However, the truck industry appears to diverge from this framework, due to a characterized numerous of small players, indicating a fragmented structure in the sector (Bouchery et al., 2022).

1.1.1. The Train Project

Over the past years, the TRAIN research team has demonstrated capabilities in road safety, traffic engineering, and mobility, among other domains. Applying driving simulators, surveys, advanced modelling, and data analysis, they have shown their expertise in achieving predetermined milestones with strong indicators. Furthermore, the TRAIN project is actively involved in an acceptance process for the deployment of TP technologies, constantly understanding their views and requirements for future implementation (Duarte et al., 2023, Neto et al., 2023). Due to the multidisciplinary character of TP, the TRAIN project examines a range of different perspectives to provide a comprehensive overview of the technology and its effectiveness on logistics companies, truck drivers and other important stakeholders, by investigating different scenarios within the literature review and also speaking with the right people inside the logistic industry to collect feedback from all parties involved (Lourenço et al., 2024).

Therefore, the purpose of this thesis research is to contribute new viewpoints and insights to the discussion of the ongoing TRAIN project, enriching the understanding of the challenges and opportunities associated with TP.

1.2. Problem Description

Today's driving mainly involves the use of advanced technologies. For these technology solutions to ensure safety and optimal functionality, they must be strong, reliable, and trusted. Hence, trust plays an important role. Its absence can lead to negative behaviors, and, in some cases, users might hesitate to use it (Simoes et al., 2022). Furthermore, according to Neubauer et al., (2020), trust also stands out as a crucial factor in the implementation of TP, highlighting the need for trust among truck drivers and in the technology itself for the successful integration of advanced systems. However, for this study trust goes more than technology acceptance, but having an overview of the ecosystem to design a service as a system provider for multi-brand operations, promoting the creation of value and trust among all stakeholders.

Another central issue is associated with engagement. As mentioned earlier, the road freight transportation sector, characterized by a highly fragmented market, faces limited chances for platoon formation and cooperation of services, due to the network effect of an insufficient number of participants. Thus, most studies are developed in a singular company way, without considering the concept of truck multi-brand platooning (Bouchery et al., 2022). To address this issue, digital platforms are known to ensure widespread user adoption, by creating new physical and digital touchpoints oriented to customers centred between products and services. These platforms enable users to integrate different systems, facilitating dialogue, and exchanging resources (Breidbach et al., 2014).

In conclusion, the legal framework, liability, and security are other important factors. Thus, the majority of the research addressed potential hazards like hacking and emphasized technological barriers, as well as security problems (Kim et al., 2022). Also, due to the automated nature of the vehicles, which may allow for longer driving hours and lower labor costs, the regulations governing resting periods need to be reevaluated (Larsen et al., 2019).

1.3. Research Objectives

As stated before, the purpose of this study is to explore the impacts and benefits of TP operations, seeking to generate high levels of technology trust and engagement among all stakeholders through innovative service design solutions. In this regard, a literature review of TP and service design was conducted to guide the construction of a new conceptual digital platform, following certain protocols and requirements related to the sector.

Data was then collected through semi-structured interviews with experts in the logistics industry, following the requirements expected for this study. Therefore, for this reason, the primary objectives of this research include:

- Understand the past and current regulatory framework and research projects of the TP ecosystem.
- Conceptualize TP as a digital platform, by designing a new theoretical service, and exploring its potential impacts.
- Provide insights for future development and potential areas for improvement.

1.4. Research Questions

This study used a Design Science Research (DSR) approach to support the building of a conceptual digital platform, as well as service design artifacts, enabling all stakeholders to share resources and split operational costs. Therefore, this research is designed to explore three key questions within the literature:

RQ1. How does TP fit into the European road system?

A Comprehensive review of TP real environment. In order to present a comprehensive image of the entire ecosystem, this investigation seeks to understand the current state of events as well as its past.

RQ2. What are the benefits and challenges that the framework of TP faces?

Study of the pros and cons of TP implementation.

RQ3. How can a digital platform be conceptualized to support TP?

Examination of international digital platforms applicable to TP, taking into consideration the service design artifacts.

1.5. Report Outline

In this section, the present work is subdivided into five main chapters and the subjects they cover, which provide theoretical support to the project and describe how the work was carried out regarding a conceptual digital platform for the truck platooning ecosystem and are represented as follows:

- **Chapter 1** (Introduction): Starts with an overview of the study, by presenting the context of this report along with a description of the research goals and questions, and the structure of the written work.
- **Chapter 2** (Literature review): Begins by presenting the general scope of TP and its history, including research projects tested on highways, the legal European framework for the truck freight industry, the TP planning and formation, and further projects associated with multi-brand platooning. Additionally, a brief introduction of the service design context, as well as key artifacts to support our conceptual digital platform building.
- **Chapter 3** (Research Methodology): Presents the research design and methodology detailed for the current work, which introduces what methods were used to collect information and the strategy of our analysis plan.

- **Chapter 4** (Results): Represents the insights gathered, and the models created from interviews and other theoretical sources, which presents the major topics from this research, including cost-sharing, acceptance, operational findings and future implementation of this proposed truck platooning system. It also suggests features and functionalities for the digital platform to overcome future operational challenges.
- **Chapter 5** (Conclusions and future work): This chapter provides practical recommendations for those involved in the truck platooning ecosystem, as well as practical insights into strategies for managing operational difficulties and encouraging industry support. Also, offers an overview of the main conclusions and contributions, making suggestions for future research.

2 Literature Review

Using relevant theoretical sources, a literature review will be carried out in this chapter on Truck Platooning (TP) and the service design of a digital platform worldwide, including also important design service artifacts. This means collecting data in an organized way, assessing it, and synthesizing academic journals and articles that are already published and relevant to this study.

2.1 Truck Platooning

Truck Platooning (TP) refers to a driving technique, where two or more trucks travel together in a close formation at the same pace, always assisted by automated driving systems and advanced communication technologies (Barua et al., 2023). This strategy incorporates digitally connected trucks that are guided by intelligent driving systems for cruise control, lane keeping assistance, and automated braking, allowing them to travel closely and in parallel (Scholl et al., 2023). Most trials conducted under the TP framework chose to use Cooperative Adaptive Cruise Control (CACC) algorithms for more communication string stability, rather than Adaptive Cruise Control (ACC) systems, which only managed speed and distance and ignored the majority of cooperative kinematic information among platoon members. Consequently, in cases of significant speed fluctuations, vehicles could be at risk of crashing at any moment (Won et al., 2021). However, based on the study by Nowakowski et al., (2015), it was reported that there is a distinction between CACC technologies and the TP framework, and they should be regarded as separate entities. TP is expected to have both lateral and longitudinal control automation, whereas CACC predominantly focuses on automating speed control while drivers retain responsibility for steering and monitoring. Thus, in terms of vehicle automation, the introduction of the SAE J3016 framework (Appendix A) has provided distinct levels of automation designed to categorize and explain each level clearly, ranging from 1 to 5. At level one, the vehicle manages its speed, but the driver remains responsible for steering. This corresponds to the typical functionality of Adaptive Cruise Control (ACC). Level 2 means the vehicle can steer itself too, however, the driver must constantly supervise the driving activity and vehicle surroundings. At higher automation levels, the vehicle allows the driver to divert his/her attention towards non-driving tasks, but at level 3 the driver still acts as fallback of the automated driving system, needing to take over when requested. Levels 4 and 5 mean full automation, albeit the former is only available at predefined roads/environments. TP can operate at various levels of automation, depending on how much the driver needs to do. Most studies are focusing on levels where drivers are still actively engaged (Calvert et al., 2019).

TP, by definition, integrates different technology solutions to capture longitudinal and lateral movements, ensuring operational efficiency and safety along the way. Hence, as illustrated in Figure 2.1, these solutions include Radars and Lidars, Global Positioning Systems (GPS), and Vehicle-to-Vehicle (V2V) communications.

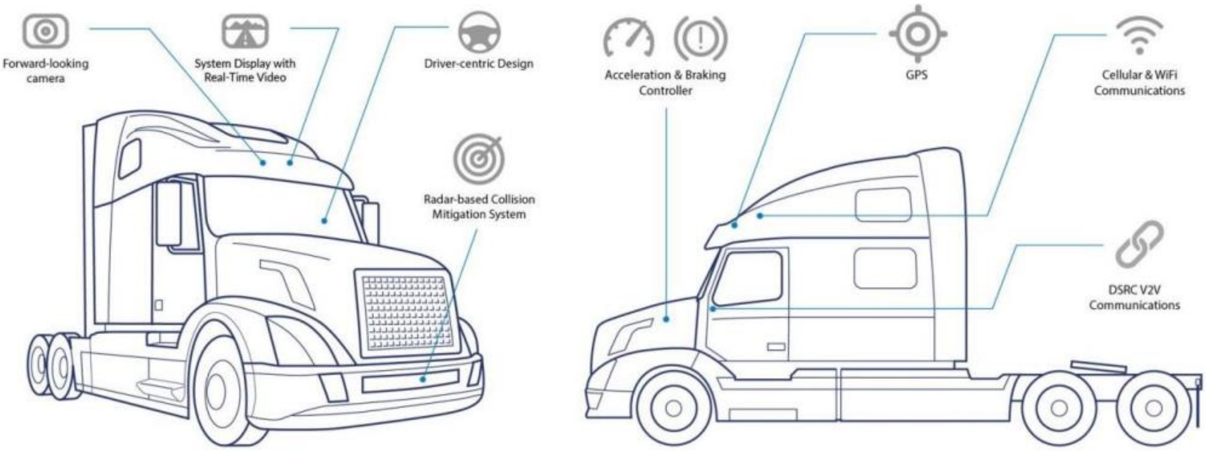


Figure 2.1: Platooning Technologies - From: Jacob et al., (2018).

Lateral guiding uses camera systems to detect road markers, reduce blind spots, and provide contextual information to drivers participating in platooning. However, the application of this strategy is compromised by adverse conditions, such as rain or snow, which may reduce visibility in the nearby surroundings. Furthermore, GPS has the potential to be used for accurate worldwide positioning with an accuracy of 0.05 to 0.10 meters. DSRC at 5.9 GHz and WiFi IEEE 802.11p are two other communication methods that are highlighted for connecting trucks in a platoon. These protocols facilitate braking synchronization and vehicle joining or leaving maneuvers. Thus, these protocols ensure the effectiveness of V2I communication methods, which include network or cloud-based communication or WiFi transmission, using centralized control management to facilitate functions such as platoon formation and grouping multiple vehicles (Jacob et al., 2018).

Studies on TP have generally shown major advantages for both industry and society. These include reduced fuel consumption and emissions, more efficient use of staff and assets, higher road capacity, and improved safety (Lee et al., 2020). The main advantage would be the reduction of fuel consumption by reducing emissions between trucks, leading to lower costs for trucking companies. Typically, each truck in a platoon experiences a 10% reduction in fuel consumption. Apart from that, platooning helps cut emissions, contributing positively to the environment. Also, truck driving times might be maximized through platooning, helping with labor expense and absence management. Therefore, the laws related to the following vehicles may ultimately be amended or eliminated, due to their autonomous nature. In addition, platooning makes the allocation of vehicles more effective, increasing their productivity and range. Making the most of the already existing roadways also can lower traffic congestion and delays for all users of the roads. Lastly, platooning improves road safety by decreasing human errors through increased automation, leading to fewer incidents, and promoting a safer road environment (Janssen et al., 2015).

Despite the potential benefits, several obstacles could affect the implementation of the TP context. First, compatibility difficulties among vehicles from different brands within the same platoon require high levels of collaboration among stakeholders. Second, user adoption and acceptance are critical factors, as many truck drivers perceive manual driving as safer, as do other road users. Also, technology investments are very expensive for truck companies, with each truck estimated to cost between 8 and 10 thousand euros, by equipping each vehicle with platooning technology. As a result, ensuring a fair distribution of costs is problematic, given the uncertainty about which vehicles are expected to benefit in terms of fuel savings and driver wages, as these benefits may vary depending on the truck's position, so third-party management should be adopted to ensure fairness. Finally, the lack of global legal frameworks for TP may block the general widespread implementation of large-scale Truck Platooning (Paddeu et al., 2021).

2.1.1 History of Truck Platooning

Truck Platooning (TP) has been the subject of many studies globally, based on the rapid leveraging of Intelligent Transportation Systems (ITS) and autonomous vehicles (AV) (Zhang et al., 2020). In the mid-1980s, in response to the increasing concern about rising traffic congestion, the University of California developed an innovative program called PATH. This initiative tested regular cars on highways, following the same path, using radars, wireless communication, and automated systems (Shladover 2007). Nevertheless, during that time, most studies focused primarily on passenger cars, so the introduction of the CHAUFFEUR project in the mid-1990s, was considered the pioneering work in the field of TP, by approaching a two-vehicle platoon with a 7.5-tonne medium-sized truck, installed with robust systems for engine management, friction control, steering, and retarder brake (Fritz et al., 1999). In the early 2000s, the California PATH program once again initiated additional projects that focused on heavy trucks for the TP context. This initiative came after prior testing on cars, recognizing the potential advantages of extending test efforts to trucks. They conducted experiments involving automated longitudinal control functions to assess the effectiveness of platooning in saving energy and increasing highway capacity (Tsugawa et al., 2016). In the last decades, countries have been working on and testing control systems for groups of trucks travelling closely together. From 2005 to 2009, the KONVOI project tested a group of four heavy trucks, with a following distance of 10 meters, both on closed tracks and public roads in Germany (Lu & Shladover 2011, Tsugawa et al., 2016). As shown in Figure 2.2, when a driver, at a distance of 60 meters from the front vehicle, decided to take part in the platoon, he/she submited a request through the interface, known as the Driver Information System, which then transmitted it to the central server via mobile and GPS communication. Upon receiving the confirmation, the target distance is reduced to at least 10 meters to form the platoon.

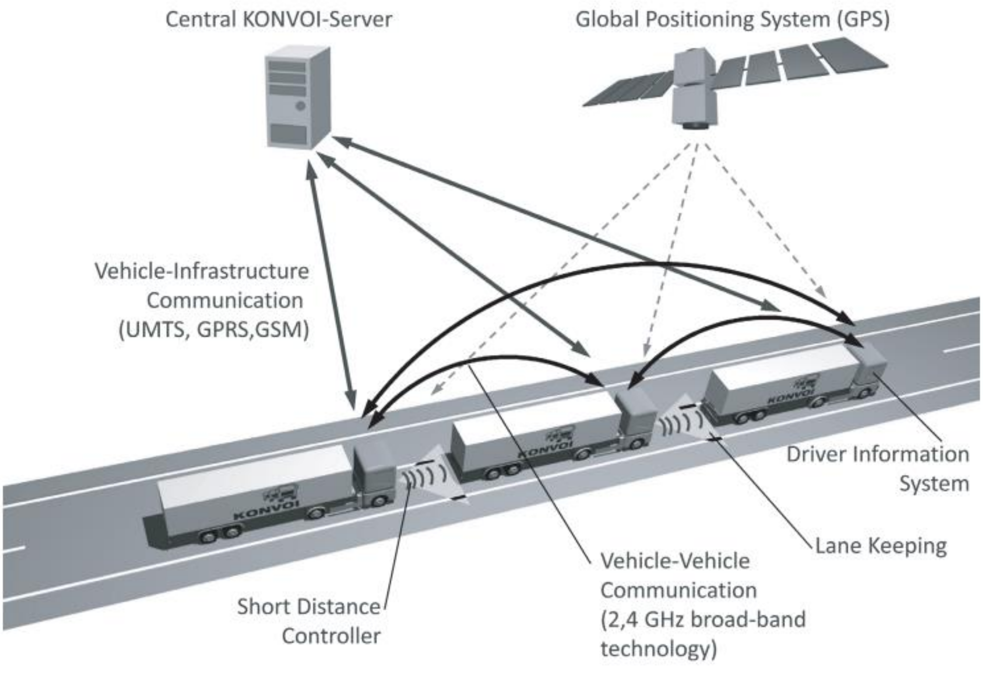


Figure 2.2: KONVOI concept and its components - From: Lank et al., (2011).

This project focused on legal aspects under real traffic conditions for the first time in Europe, however, for safety and legal considerations, the tests involved project engineers, guided by a BF-3 escort vehicle and a police car, limiting some phases of the tests in real scenarios (Lank et al., 2011). In 2008, the Energy ITS began its studies in Japan, for 5 years, focusing on fuel and energy indicators, used only on motorways, since the system needed road marking for lane control. The research included various scenarios with different maneuvers, such as, lane changing, and vehicles cutting in. The results on empty trucks showed 13% energy savings, at a 10-meter gap, and 18% at a 4.7-meter gap, driving at a steady 80km/h. When fully loaded, the average savings are 8% at a 10-meter gap and 15% at a 4.7-meter gap (Tsugawa et al., 2016). Between 2010 and 2012, the European project SARTRE experimented a platoon of five vehicles, including two trucks and three passenger cars. The SARTRE project implemented technology to automate and control both longitudinal and lateral positions, including as a base, V2V communications via mobile on the IEEE 802.11P, on the 5.9 GHz frequency band, to frequently access important data such as the presence of an intruder, their distance, and speed, as well as the intended platoon speed and braking. The results showed that the leading vehicle achieved fuel savings of 16% with a 5-meter gap and 8% with a 15-meter gap. Similarly, the following trucks saw savings ranging from 12% at a 7-meter gap and 4% at a 15-meter gap (Balador et al., 2022). In the following years, the project COMPANION, supported also by the European Commission and concluded in 2016, was mainly focused on predicting how much fuel was spent during the operations, as well as new solutions to coordinate platoons using a real-time coordination system (Lesch et al., 2021). The COMPANION project goes beyond the technical components, dividing the prior planning through an off-board platform. This platform includes data regarding how a platoon forms, and when they can merge or split on highways. It was acknowledged that the lack of EU legislation and considerations across all member states is one of the barriers towards the effective deployment of TP (Eilers et al., 2015). So far, all previous studies were conducted from the perspective of individual companies, without cooperation between different brands or operators. This lack of cooperation limits the available data for further development, such as splitting costs from energy, driver's wages and assets management.

2.1.2 Legal European Union Framework

Based on the European Union legal framework, mentioned in (EC) No 561/2006, certain rules were established for companies to work in road transportation, and also to ensure safe work conditions for truck drivers across all European states. These specific rules are concerned with heavy goods vehicles weighing over 3.5 tonnes, buses, or vehicles with 10 or more seats, being mainly focused on driving and resting times, as well as record-keeping through the use of a tachograph to be shown as evidence to the legal authorities. To summarize some important guidelines, Table 2.1 is presented below:

Table 2.1: European Union Rules Framework for Road Transportation.

Driving Times and Rest Periods
Maximum of 9 hours per day, which can be extended to 10 hours twice a week.
Weekly driving time is 56 hours, with a maximum of 90 hours over two weeks.

A rest break is required for every 4 hours and 30 minutes of driving time, at least 45 minutes.
Drivers must take at least 11 hours of rest for every 24 hours of service.
Drivers are allowed to work up to 60 hours per week on average over 4 months, but not exceeding 48 hours in a single week.
Two or more drivers can share driving responsibilities within 30 hours, with 45-minute breaks required for every 4 hours and 30 minutes of driving.
Specific Situations
A tachograph is mandatory for recording driving times and keeping records for at least a year.
A regular weekly rest period of at least 45 hours is required, during which drivers cannot remain in the vehicle.

Therefore, these regulations play an important role in ensuring safety conditions on roads, as well as the compliance with EU transportation standards. Thus, individuals or companies who do not comply may face penalties or legal actions.

Nevertheless, with the deployment of TP, on public roads, it becomes evident that certain EU legal standards, presented previously, may need amendments, as the driving and resting times will often involve collaboration between two or more truck drivers, among whom these hours can be splitted during the journey.

2.1.3 Truck Platooning Planning

Based on Bhoopalam et al., (2018), platoons can be formed spontaneously without prior planning. Although, in the early stages, meticulous centralized planning is necessary to initiate platoons, due to locations where the technology adoption of TP is not widespread, and in most cases, a platooning service provider could coordinate trucks from different brands to organize and schedule the prior platoon planning process.

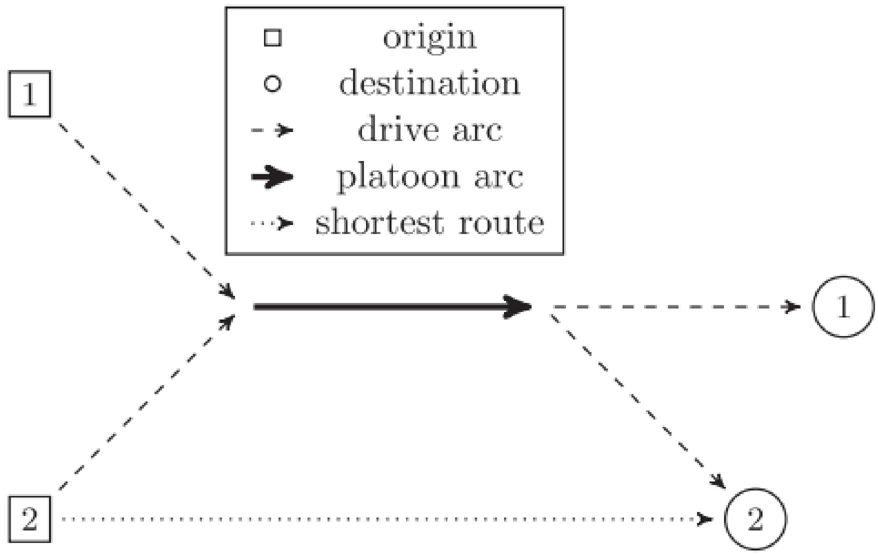


Figure 2.3: A two-truck platoon - From: Bhoopalam et al., (2018).

As illustrated in Figure 2.3, a two-truck platoon is represented to show a scenario where one of the trucks adjusts its path, to facilitate the formation of the new platoon. This suggests the need to synchronize departure times, travel speed, and routes, as well as the need to change its route to join new platoons to share resources. Additionally, Bhoopalam et al., (2018), divide TP planning into three different scenarios:

1. The platoon scheduling – where all trips are announced prior to the operations even starting;
2. Real-time platooning – occurs when trucks announce the intention to merge into an already scheduled platoon, shortly before departure or even while already on route;
3. Opportunistic platooning – where platoons form spontaneously without planning processes, is also referred to as on-the-fly platooning.

From another perspective, Abdolmaleki et al., (2021), affirm that systematic planning is essential to join a platoon together both in space and time, to converge fleets at suitable places, with less congested sections of highways. Thus, an optimized route ensures that the benefits of fuel efficiency from TP are realized, and it can be approached either offline or in an online manner. However, two main problems arise with the current research. First, many of the proposed methods are not very good at optimizing, facing strong challenges within a massive number of trucks in large networks. Second, the way these methods are defined makes it hard to plan, due to the complexity of real-world problems, because most of them make assumptions that would not be correct in certain contexts (Abdolmaleki et al., 2021).

2.1.4 Multi-Brand Platooning

Truck Platooning (TP) might be seen as logical when organized for a single company context, however, its deployment does not align with the structure of the truck industry, which is characterized largely by small entities. Therefore, the advantages can only be fulfilled if multiple stakeholders in the trucking sector collaborate to form platoons (Bouchery et al., 2022). In 2016, the project European Truck Platooning Challenge (EU TPC) introduced new perspectives within the multi-brand context, being the first cross-border initiative in the world to showcase six different brands departing from various locations in Europe, with the final destination at the APM terminal in the Port of Rotterdam.

This project was conducted with 79 stakeholders, including manufacturers in the truck industry, such as DAF, Daimler, IVECO, MAN, Scania and Volvo, focusing on topics, such as technology, operations, infrastructure, legal issues, human factors, external road users and driver acceptance. Throughout this challenge, each brand operated one truck platoon with a fleet of 2 or more trucks, starting from Sweden, Denmark, Germany, Belgium, and The Netherlands, proving a great success since it was capable of testing and understanding how each country could manage TP deployment for cross-border corridors across Europe. Hence, most of the advantages shown were as expected, such as enhanced traffic safety by the CACC technology, optimized road capacity, fuel efficiency and emissions reductions, and decreased labor costs.

However, it was reported some challenges during the assessments. Firstly, the freeway layout across the EU varies between regions, mainly due to lane different cross-sections adopted in each country (e.g., some countries use an emergency lane, restricting heavy or light vehicles from trespassing on it). Secondly, the complexity of the traffic scenarios, including factors like traffic density and weather conditions, differed from country to country. Thirdly, considerations regarding tunnels are also important, as tunnels can disrupt TP technology from behaving normally due to communication problems between the fleet. Lastly, variations in maximum speed regulations among EU countries added more complexity (Aarts et al., 2016).

Hence, Aarts et al., (2016) reported several important considerations for the future success of real-life TP implementations. These include new cross-border initiatives, explaining the need for standardization of communications, driver certifications and involvement with end-users as shippers and hauliers, and optimizing the utilization of existing infrastructure, by clearly defining which roads are suitable for TP operations, enhancing the attractiveness of the technology. So, setting up some guidelines for road authorities about responsibilities is crucial, as well as fostering monitoring and transparency between countries for accelerating learning and providing feedback loops.

Despite the EU TPC’s success, standardization was revealed as a key limitation, since each manufacturer system only worked with its trucks or technologies. So, in 2018, a new project called ENSEMBLE was initiated to ensure that different truck companies could convoy safely across Europe inside a digital network. With a similar goal as the EU TPC project, the vision of ENSEMBLE was to harmonize all partners' specifications for multi-brand V2V communication protocols, thus establishing new standards for the TP context (Willemsen et al., 2023). Besides that, ENSEMBLE, aimed for two types of platooning functions: (i) the Platooning Support Function (PSF), related to SAE levels 1 and 2, which involves longitudinal control, with the truck driver remaining responsible for certain functions of the truck, and (ii) the Platooning Autonomous Function (PAF), where the leader vehicle assumes SAE levels between 1 and 2, and the following trucks fall within SAE level 4, involving both longitudinal and lateral control, and where the system would be responsible for most of the tasks during the TP operation. Thus, as shown in Fig. 2.4, the project operated on a hierarchical structure, applying interacting layers with distinct functionalities and specific responsibilities: (i) the service layers serve as the digital platform for logistics companies' operations, (ii) the strategic layers handle the high-level decision-making, including scheduling, optimization of fuel consumption, vehicle compatibility and travel times, (iii) the tactical layers coordinate platoon formation, between merges and splits, ensuring no collisions, since they are responsible for maneuver initiations as well as the V2X communication protocol inter-vehicle, and (iv) the operational layer was responsible for the acceleration, braking and steering (Mascalchi et al., 2020).

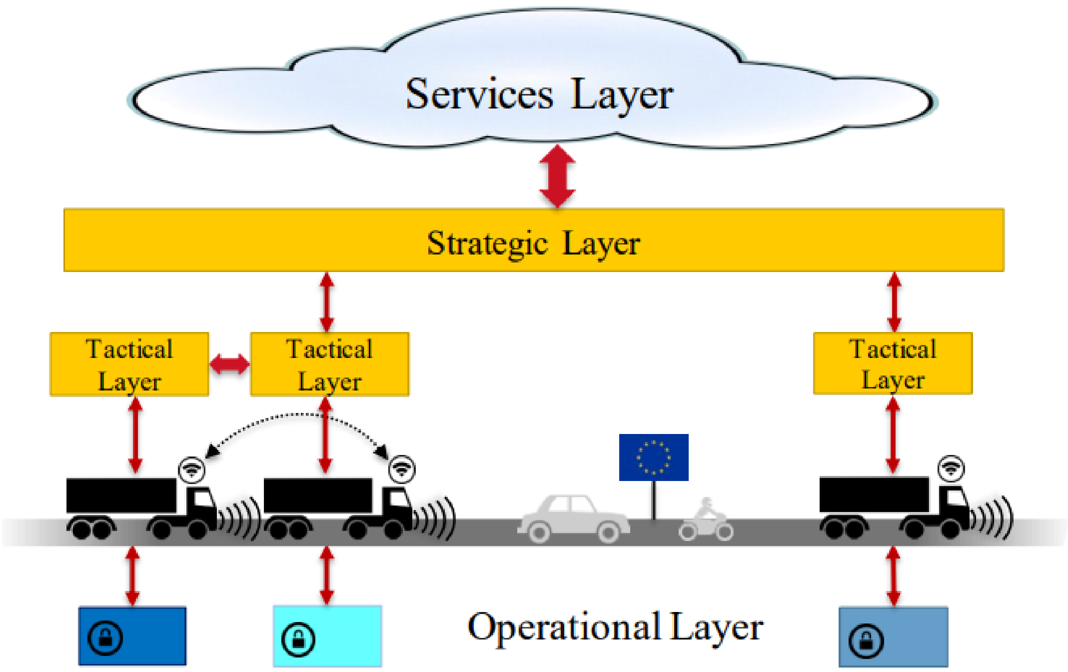


Figure 2.4: ENSEMBLE Platooning Layers - From: Mascalchi et al., (2020).

As a result, several key conclusions from the project ENSEMBLE were defined (Konstantinopoulou et al., 2019):

- Verbal communication effectiveness should be ensured, as in some cases language differences among truck drivers could cause a barrier for future platoons and decrease safety in operations;
- Standards for regulatory requirements must be established, to avoid impact on testing and verification processes for platooning systems on roads;
- More specifications regarding messages, icons or other visual elements are required, to facilitate further development.

Besides all the efforts invested in the recent multi-brand projects, researchers faced most of the issues related to the standardization of processes and protocols worldwide, as well as the lack of a trusted digital network where TP stakeholders could collaborate to combine platoons and share resources and costs during operations.

2.2 Service Design

Service Design refers to a multidimensional procedure, human-centred, focused on creating or improving services to be more innovative, by knowing the circumstances, social practices, and specifications of both consumers and service providers. This understanding is then translated into the development of evidence, and the interactions, between service systems. Thus, includes features from a range of subjects, such as operations, marketing, service management and technology domains, as well as information systems as well as interactions design (Teixeira et al., 2018).

Applying a range of action-oriented techniques, design science research (DSR) has refined multiple components of services. These techniques from design science promote collective understanding by generating innovative future ideas, which facilitates expert analysis and problem-solving, for a collaborative service design. Initial methods in service design research include blueprinting, in order to focus on the front and back ends of service delivery, but eventually, they shift to other components of the service, aiming for the service interfaces, as the central role (Teixeira et al., 2019). Moreover, some of the models for creating the service idea from a management point of view concentrate on the company's value proposition, which represents the service offerings and their relationships from the customer's perspective (Grenha Teixeira et al., 2017).

2.2.1 Business Model Canvas

Osterwalder & Pigneur (2011), affirms that for an organization to be successful, it must generate value in order to ensure it earns more revenue to cover all business expenses. Therefore, the model proposed, named Business Model Canvas (BMC), defines the logic behind how an organization creates, delivers and captures value, covering the main areas of the business logic: customers, offer, infrastructure and financial structure. Thus, this universal model intends to propose an intuitively understandable approach to all complex business operations simplified.

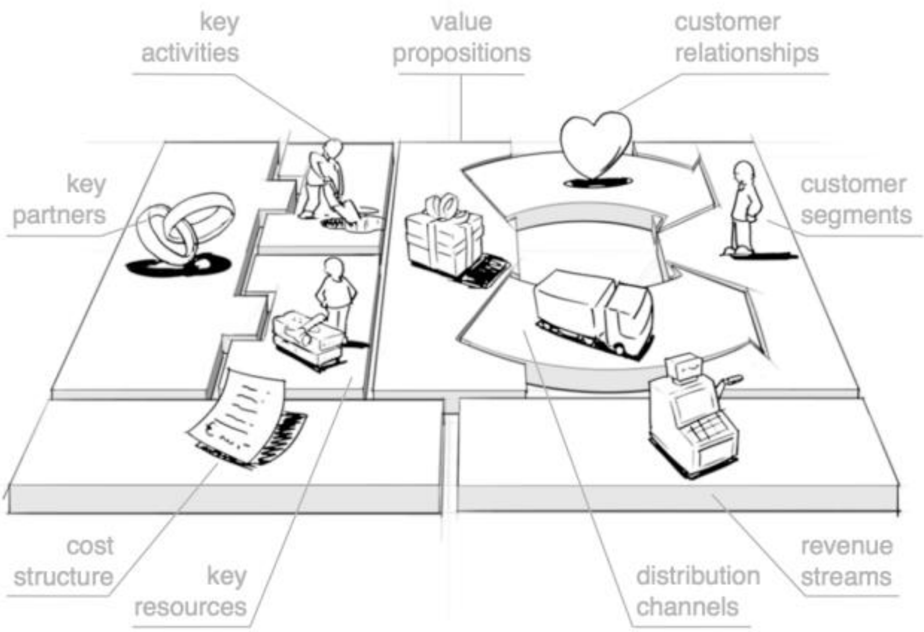


Figure 2.5: The Business Model Canvas - From: Osterwalder & Pigneur (2011).

As illustrated in Figure 2.5, BMC is divided by nine blocks (Osterwalder & Pigneur 2011), each characterized as follows:

- The value proposition defines the products and services that create value;
- The customer segment identifies different groups of individuals or companies to target;
- The distribution channels describe how the organization's communication will happen and how will be delivered the value;
- The customer relationships block outlines the types of relations between the company and its customer segments;
- The revenue streams represent the cash flow that the organization will generate from each customer segment;
- The key resources describe the essential assets required for the business model to function;
- The key activities identify actions for a company to take its business model to work;
- The key partnerships detail the network of partners that will help to make the idea work;
- Lastly, the cost structure defines all the key costs involved when operating a particular business model.

Nevertheless, the ideation phase holds great importance in order to create a strong business model canvas (BMC), which is essential for creatively generating different ideas and defining the most promising one. Nowadays, new business concepts must challenge conventional thinking and create original models that address new or hidden customer needs (Amanullah et al., 2015).

2.2.2 Service Blueprint

The initial goal of the service blueprint was to provide exact control over what the service will deliver, which provides a variety of advantages, such as locating possible trouble spots, as well as identifying issues before they happen. Hence, its strategy is similar to other business process mapping techniques, which may be used to provide basic overviews and breakdowns, using images and symbols to show who performs what. They are meant to be simple to use by everyone involved, including managers, staff and customers, compared to some models, like UML or BPMN, which may get highly complex.

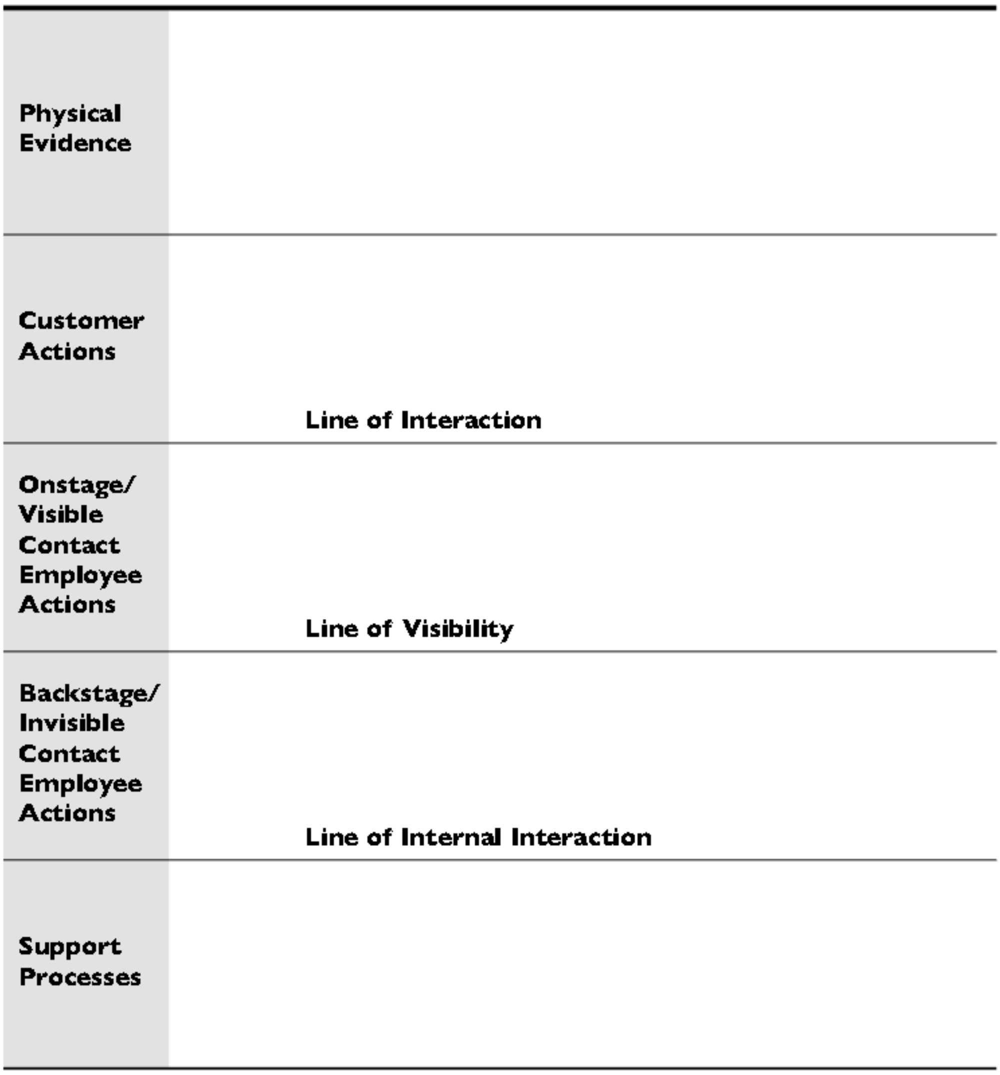


Figure 2.6: Service Blueprint Components - From: Bitner et al., (2008).

Based on Figure 2.6, a typical service blueprint model consists of five elements. These elements include: (i) the customer actions that take part in any customer journey during the service delivery process; (ii) the onstage/visible contact employee actions which are divided from the consumer by the line of interaction and represent the frontline contact between customers and employees; (iii) the backstage/invisible contact employee actions, which includes operations that are not visible to customers to serve clients and maintain the service; (iv) the support processes that represent tasks that are not performed by employees, but they are necessary for the service to be provided; (v) and lastly, the physical evidences that are all tangibles assets that consumers perceive the quality of the service (Bitner et al., 2008). Therefore, this tool can be helpful in managing and controlling existing services, creating new services, and comprehending client preferences, and also be beneficial for enhancing internal communication within the organization (Kostopoulos et al., 2012). Alternatives to blueprinting include service and business process mapping and notation (BPMN) mapping. This represents key parts of a repeatable service process with multiple actors and a customer (Milton & Johnson 2012).

2.2.3 Business Process Model and Notation

According to Chinosi & Trombetta (2012), Business Process Model and Notation (BPMN), is a common standard model for business process modelling that combines graphical notations to specify business processes, leveraging traditional flowchart techniques and focuses on supporting both technical and business users by providing a notation that is easy for business users to understand while being capable of representing complex process details. Besides, it's an approach that intends to be easily comprehensible for those who design refine, implement and manage them. The BPMN 2.0 includes execution semantics and bridges the gap of communication between design and implementation.

BPMN is a helpful tool for new initiatives in the enterprise architecture domain aiming at managing changes in order to enhance business processes by combining different crucial topics such as process modelling, simulation, workflows, enterprise application and B2B integration into a single approach. Hence, this model describes the events that start the process, the actions needed to be performed, the outcomes of the flow, and the decisions represented using gateways. Also, it helps to define individual tasks by clarifying who does what in certain situations, characterized by lanes and pools (Owen & Raj 2003).

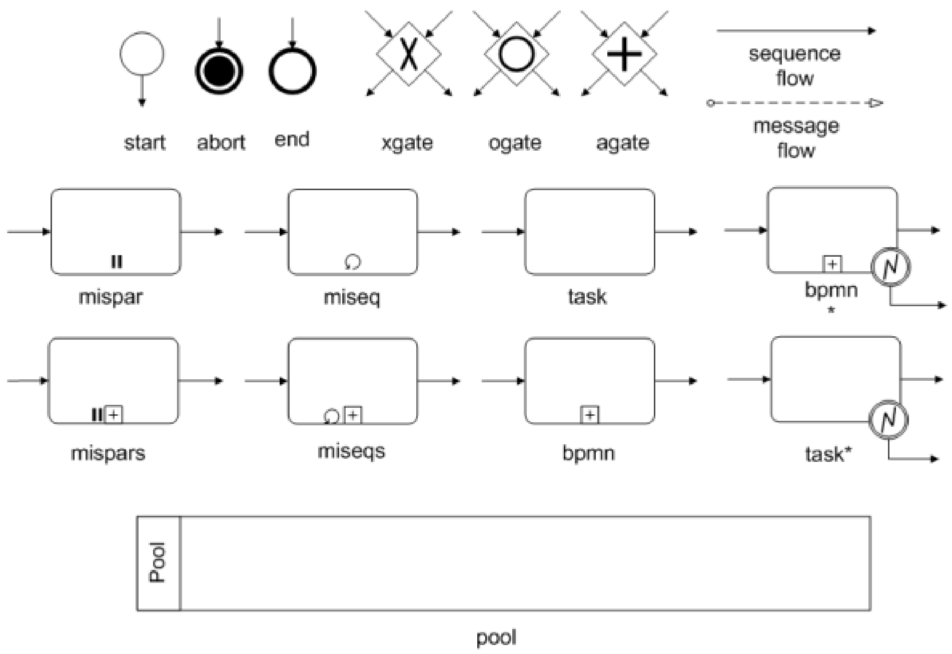


Figure 2.7: States of BPMN diagram - From: Wong & Gibbons (2008).

Based on figure 2.7, BPMN schema is presented showing each type of state that can be defined by pools, tasks, sub-processes, multiple instances, or control gateways, connected by sequence and message flows (Wong & Gibbons 2008).

2.3 Software Design

The Internet of Things (IoT) revolutionizes everyday objects by giving them sensing and processing capabilities and connecting them to the Internet. This allows for the creation of new services and improves the efficiency of existing processes. Hence, IoT devices generate enormous volumes of data, which affects many industries, including logistics and transportation, by providing stakeholders with real-time data for efficient resource allocation and route planning. However, in order to properly employ IoT technologies, obstacles in the hardware and software domains must be overcome, particularly in terms of mobility, energy optimization, and efficient data management (Giao et al., 2022). Valipour et al., (2009) describe software architecture as the overall system structure that provides sufficient detail for enhanced comprehension and assessment. It influences development phases by acting as a bridge between the intended functionality of the system and its implementation through six key factors: comprehension, reuse, building, evolution, analysis, and management. Hence, many software architecture styles, such as monolithic, service-oriented architecture (SOA), and microservices, have been defined as essential blueprints for creating and structuring complex software systems. Each reflects the demands of contemporary software systems, concerning their advantages and difficulties. Although a classic monolithic was common in the past, it now has issues with scalability and dependability. As other applications get

more complicated, it also has concerns with growth and coupling. Microservices and service-oriented architecture (SOA) are intended to address most of the issues with traditional monolithic design. Nevertheless, they also introduce new challenges, such as additional testing tasks and deployment costs (Liu et al., 2020).

The primary issue with the old monolith was interoperability, and the SOA architecture style was chosen as a practical solution. Researchers coupled SOA technology with IoT systems to address integration issues across several networks and independently operating apps. Service-oriented architecture (SOA) enhances corporate intelligence, performance monitoring, and security threat detection capabilities. It also has the scalability to adapt to fluctuating demand levels. Thus, by providing agility in responding to business changes and easing connections with consumers, partners, and suppliers, it successfully satisfies the objectives of IoT applications. Furthermore, SOA includes two main approaches: SOAP and RESTful. While SOAP serves as a protocol specification for structured information exchange during web service implementation, REST focuses exclusively on the actual message exchange. However, SOAP has restrictions such as tightly coupled invocation and a lack of hyperlink support, RESTful services are preferred for IoT applications due to their increased flexibility, ease of learning, and implementation (Gupta et al., 2018). Thus, REST adopts HTTP protocol concepts like GET, PUT, POST and DELETE, to read, update, edit, create, or delete resources state (Pencheva et al., 2016).

2.3.1 Microservices

Microservices have emerged as a fresh approach to architectural styles for enterprise software, diverging from traditional service-oriented approaches. They help to update large monolithic systems by cutting them down into a set of interacting services, aiming at how applications are structured internally. However, given the size of most monolithic systems, sometimes it's tough to modernize them all at once, instead, it's done gradually step by step (Knoche 2016).

This type of architecture has the ability to operate through multiple interfaces across different infrastructures, diverging from the normal monolithic vertical development approach. Thus, his evolution fosters security enhancements by enabling the use of multiple programming languages, APIs, and serverless techniques, along with the flexible scaling of resources as required. Its composition has several characteristics, including being easy to scale for more additional services, as well as the fact each service can be independently deployed, simplifying maintenance by working with small amounts of code, and turning their build lighter. Also, it provides heterogeneity and multilingualism, so programmers can choose the most suitable coding languages for each service, making it easy to rewrite and create new services. Hence, each service is isolated from the rest of the application, so failures only affect the respective service, preventing failures from spreading to the rest of the system. To conclude, the communication between teams is improved, due to the creation of a Full-Stack team that collaborates as a single unit (Mateus-Coelho et al., 2021).

Based on Figure 2.8, applications are divided into small partitions, doing their job, running inside small containers, and having private databases that others cannot access directly, enhancing the performance of serverless cloud applications (Liu et al., 2020).

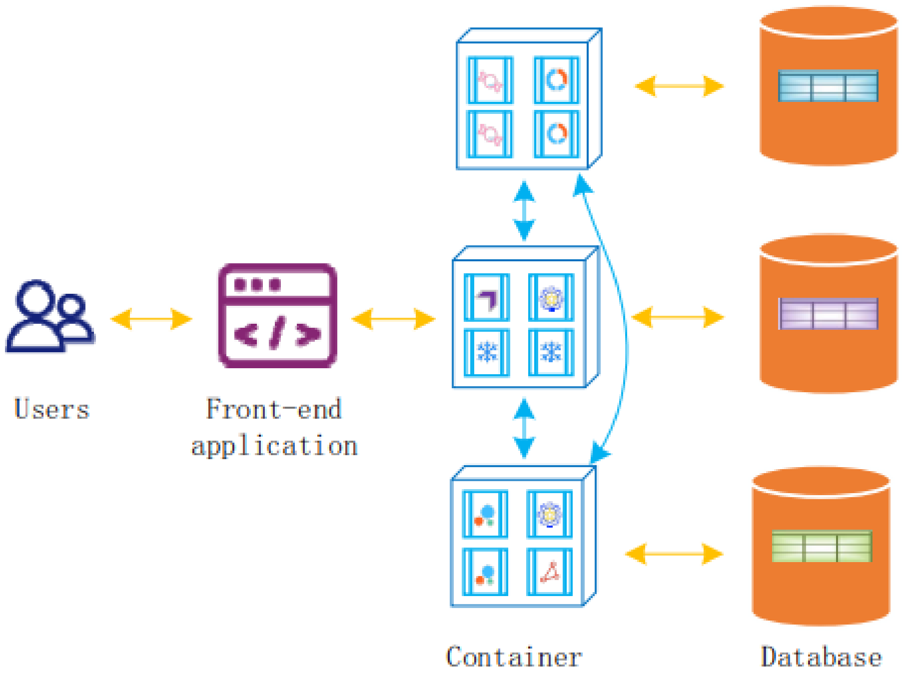


Figure 2.8: Microservices Architecture - From: Liu et al., (2020).

This architectural pattern has been applied to worldwide companies like Amazon, Netflix, and LinkedIn, to support and scale their applications and products. However, this approach sometimes causes an extensive effort for the teams regarding time and resources, and to make it easier, one of the cloud providers like Amazon Web Services (AWS) lets companies deploy microservices without managing servers, and the costs are based on the number of requests through the application, so developers only focus on writing code and the deployment management of each microservice is automatically sent to AWS, named as Amazon Lambda (Villamizar et al., 2016). Hence, the Amazon Web Service Cloud Platform provides more services, like computing, networking, storage, content delivery, databases and serverless (AWS Lambda) for web applications. In terms of computing, it is easier for developers to scale applications due to its complete control of computing resources, and it is defined as Amazon EC2. For networking, the Amazon VPC provides multiple layers of security, thereby it is possible to create a connection between a VPN from the Amazon VPC and company information for better data protection. Regarding storage and content delivery, Amazon S3 helps developers safely retrieve any amount of data, at any moment, from any part of the world, and the objects stored can be written, read and deleted inside the so-called buckets with control of access. Finally, the Amazon RDS facilitates the operations and scalability of relational databases inside the cloud by managing different languages, such as MySQL, Oracle, SQL, and PostgreSQL, being flexible for applications API calls (Mathew & Varia 2014).

2.4 Developing Technology – Enabled Services

2.4.1 System & User Requirements

Defining system requirements is a crucial step in designing the overall system, which is essential for technical designers, as well as users that will engage with the system, and it is divided by hardware and software specifications. Thus, they need to be clearly defined to establish precise expectations that match what users need in the new system and how those should be achieved. In fact, when users are not consulted regarding what they need, systems quality often suffers, resulting in poorly designed systems. In such cases, if there is a lack of technical specialists inside the organizations, interviews must be carried out with market experts or independent consultants are essential. Therefore, understanding the implications of the new technology implemented and how the system must operate is indeed an important aspect of future vision (Mumford 1985).

Concerning user requirements, they are also a fundamental approach for designing information systems, being widely known as crucial for the success of the interaction between the user and the system, since the start of any service or product must attend to user needs and requirements, leading to lately reduced support, training costs, increase productivity, improve quality of work, and better user satisfaction. Although, requirements analysis is not an easy process, due to analysts often seeing challenges, such as complex organizations with many stakeholders users or designers with traditional thinking patterns (Maguire et al., 2002).

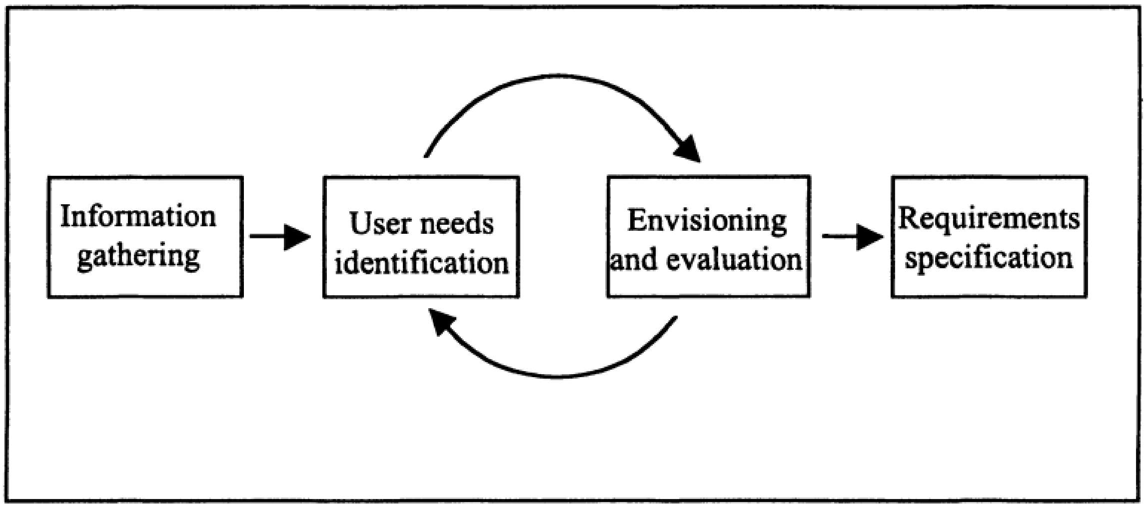


Figure 2.9: General process for user requirements analysis From: Maguire et al., (2002).

As highlighted in Figure 2.9, four stages are defined in order to help approach the user requirements phase: the information gathering represents the analysis of the users and stakeholders and the current processes of the system; the user needs identification, which is usually for collecting data, including methods, such as, user surveys, focus groups, interviewing, scenarios and use cases, workshops and evaluating competitor's systems, to help to identify those needs; the envisioning and evaluation that is characterized by developing a prototype to represent the service or product, in order to validate and refine those requirements with the user feedback, described as, brainstorms, card sorting, affinity diagramming, storyboards, prototyping, allocation of functions, design guidelines and standards and parallel design; and to conclude, the requirements specification illustrates user and organizational final requirements, that should be stored, however, it is clear the importance of management changing as long as the system grows and develops. This includes the mapping of tasks and functions, that specify functions by each user task, where those relationships are shown to ensure all are fully supported (Maguire et al., 2002).

2.4.2 Subscriptions

The leverage of digital solutions has enabled consumers access to a wide range of digital resources, such as software services, music, movies, and e-books, with different types of pricing schemes defined by digital providers, including ownerships and subscriptions. The worldwide company Salesforce was pioneered, in the 1990s, introducing the subscription model (Zhang & Zhang 2024). Furthermore, as per Chen (2023), subscription models are seen as common in e-commerce to deliver products as services regularly, monthly or quarterly, through business subscription programs. Digital platforms offer consistent revenue to sustain long-term business structures letting customers enjoy digital items at lesser prices, with the freedom to renew or cancel their subscriptions as desired, like most of the competitive worldwide companies, such as Netflix, Apple iTunes and Spotify. Thus, they often use free trials, to retain or attract potential customers, with 14-day or 30-day free trials as a strategy to promote their subscription programs. Nevertheless, Kübler et al., (2021), claim that if platforms are charging higher fees, businesses might witness lower profitability with high-quality content, as consumers already anticipate high standards of products and service offerings, however, platforms with lower pricing structures could capitalize more.

While competing with free content may seem pointless, enforcing a pricing strategy that is viewed as fair may reduce the excuse for illegal actions among future "pirates," thereby motivating them to convert to paying customers (Kukla-Gryz et al., 2021).

3 Research Methodology

In this chapter the research methodology is presented, outlining how the study intends to analyze the impact and integration of TP within the European road system, evaluating its advantages and disadvantages, and a conceptualizing a digital platform to support TP operations among stakeholders, allowing the sharing of resources and reduction of operational costs.

First, given the dynamic of the technological point of view, most of the data was collected seeking theoretical and past practical implications with the assistance of the methodology named Design Science Research (DSR) enhancing the reliability of the research findings, which is suitable for developing and evaluating artifacts to solve problems, evaluating the benefits and barriers of TP applications, and supporting the creation of a conceptual digital platform by examining other global providers of digital system in real-word case studies. Then, face-to-face interviews provided valuable insights from logistic industry experts, which were used to support and refine the design service artifacts created during this study, such as the BMC, BPM, and system and user requirements, helping to understand the latest trends and opinions in the truck logistic sector.

DSR is becoming more popular in the information systems (IS) field. Design science research (DSR) focuses on the development of artifacts (Weigand et al., 2021). Thus, the goal is to develop improved solutions, whether in the form of more efficient and effective products, processes, services, technologies, or ideas, and it is viewed as a discipline centered around the utilization of information technology artifacts in human-machine systems (Gregor et al., 2013). These artifacts include constructs, which describe both the problem and the solution; models, which represent certain aspects of reality; methods, such as algorithms; instantiations, which enable researchers to test concepts within real-world conditions and learn about them; and theories, which describe cause and effect relations (Cleven et al., 2009).

According to Hevner (2007), effective DSR is considered a pragmatic philosophy, which views practical results as crucial aspects of meaning and truth. It often starts by exploring opportunities and solutions to real-life problems within the studied ecosystem. Based on Figure 3, Hevner (2007), proposes a framework for design science research (DSR) projects related to 3 cycles: relevance cycle, design cycle, and rigor cycle.

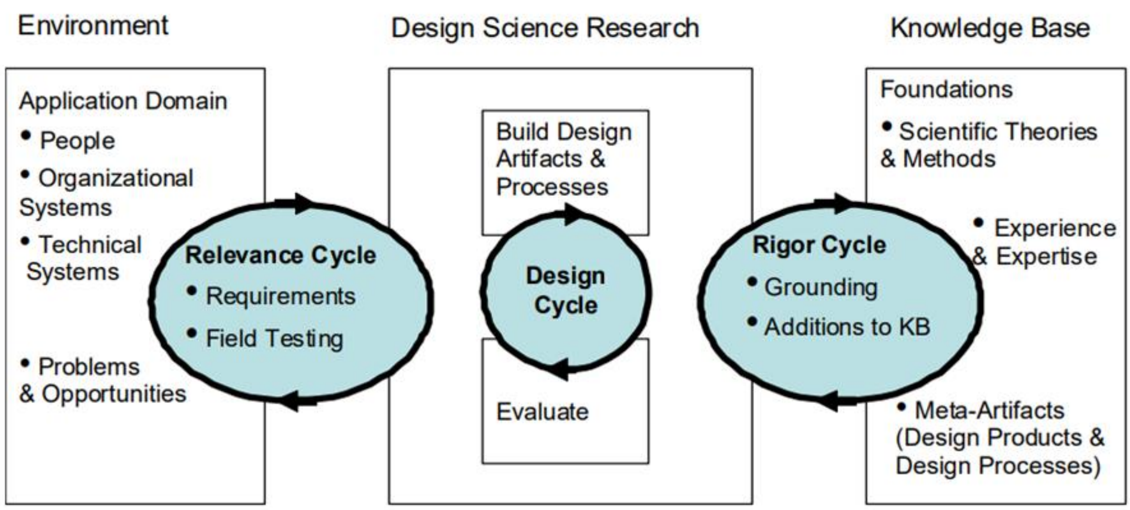


Figure 3: Design Science Research Cycles - From: Hevner (2007).

DSR is driven to improve the environment in the Relevance Cycle by bringing new and creative artifacts along with the processes that go along with them. This stage involves identifying opportunities and issues as well as an application domain made up of people, organizational structures, and technical systems. The Design Cycle phase then produces new artifacts and processes based on an understanding of their needs, thoroughly testing and evaluating them before putting them to the test in an actual setting. Additionally, the Rigor Cycle phase provides scientific knowledge base theories and engineering methods, to gain new insights from experiences and expertise from the current state of the art. This phase depends on the research rigor of building those artifacts (Hevner 2007).

3.1 Data Collection Methods

This study employed a qualitative approach to gather insights, experiences, perceptions and attitudes, from experts within the truck transport sector. This process seeks the analysis of reading, listening, and digesting, promoting engagement to uncover more themes, patterns and contradictions in participants narratives. Thus, to facilitate this, a guided semi-structured interview format was created to foster effective interactions and reveal hidden challenges within the Truck freight transport ecosystem, always seeking individuals responsible for fleet managers or truck logistics experts.

Based on Myers & Newman in 2007, social interactions are seen as a drama where there are actors (individuals and groups) who perform on a stage (a variety of settings and social situations) all guided by a script (norms, rituals, expectations of how one should behave). The actor’s appearance, manner and props are essential components during these performances. Therefore, the interview conducted has the following structure:

- **Drama** – Qualitative Interviews.
- **Stage** – Luís Simões Logística headquarters.
- **Actors** – Truck fleet managers and logistics assistants.
- **Script** – The Interview structure (Appendix B & Appendix C).
- **Entry** – The creation of a positive impact on the other side. Ethical practices. (For example: Get well-dressed and have good manners).
- **Exit** – Possibility of finding new actors to interview, by snowballing.
- **Performance** – Data can have positive or negative outcomes, leading to either good or bad performance, respectively.

3.2 Sampling Strategy

The main goal of this research project was to study the viability and specifications of a conceptual digital platform for the truck platooning ecosystem, so, the objectives were to figure out what features and requirements are necessary for such a digital platform, by identifying major operational problems, and comprehending truck industry acceptance. Therefore, logistic companies experts, such as fleet managers and logistics assistants, were selected based on their extensive experience and expertise regarding the concept of truck platooning and freight truck operations, however, the target population was done only with one company, Luís Simões Logística, due to the lack of willingness of more participants, which limited the sampling strategy for this study. More companies were contacted in Portugal, to collect more data, although no further response or cooperation for the due time of this research.

As mentioned earlier, the primary tool used to gather important data was a semi-structured interview, (Appendix B & Appendix C) written in Portuguese, guided at the company headquarters, above described, with four expert individuals, during one hour and a half, which was intended to cover key topics as follows:

- **Knowledge & Familiarity** – Understanding the participant's knowledge and experience with the truck platooning framework.
- **Acceptance and Implementation** – Interpretation of a conceptual design of a digital platform, concerning essential features, and requirements, as well as the advantages for stakeholders collaboration aspects.
- **Operational Challenges** – Identifying key operational challenges and potential solutions.
- **Cost-sharing** – Asking about the methods and standards for cost-sharing.

- **Future Perspectives** – Considerations between integration with company systems, data confidentiality, and needs for customization.

For future analysis, the interview was recorded by phone, in order to fully comprehend the viewpoints and experiences of the participants, as well as ensure accuracy throughout this research, however, the identity and responses of the individuals will remain confidential.

4 Results

This chapter corresponds to the description and evaluation of our conceptual digital application using components of service design artifacts developed during the current work, such as the Service Blueprint, the Business Model Canvas (BMC), the Business Process Model (BPM), the Requirements analysis, and the design of an architectural system designed as Microservices, to collectively provide a comprehensive view of our truck platooning application. During the first phase of this study these models were developed using transcriptions and a comprehensive literature review, although due to the face-to-face interview experts in truck logistics contributed more essential inputs, in order to refine and improve these prototype models, guaranteeing that the relationships, processes and technical components required for the creation of the digital platform application was realized and achieve the goal pretended.

4.1 Business Model Canvas (BMC)

The analysis and interpretation of this study were carried out through in-depth research of the Truck Platooning context, which supported the design of the Business Model Canvas by Osterwalder & Pigneur (2011). Hence, the model was approved by the logistics company, Luís Simões Logistics, which as well as a positive set-up to define the BMC, in order to have a comprehensive overview of how the system should operate to add value to its stakeholders.

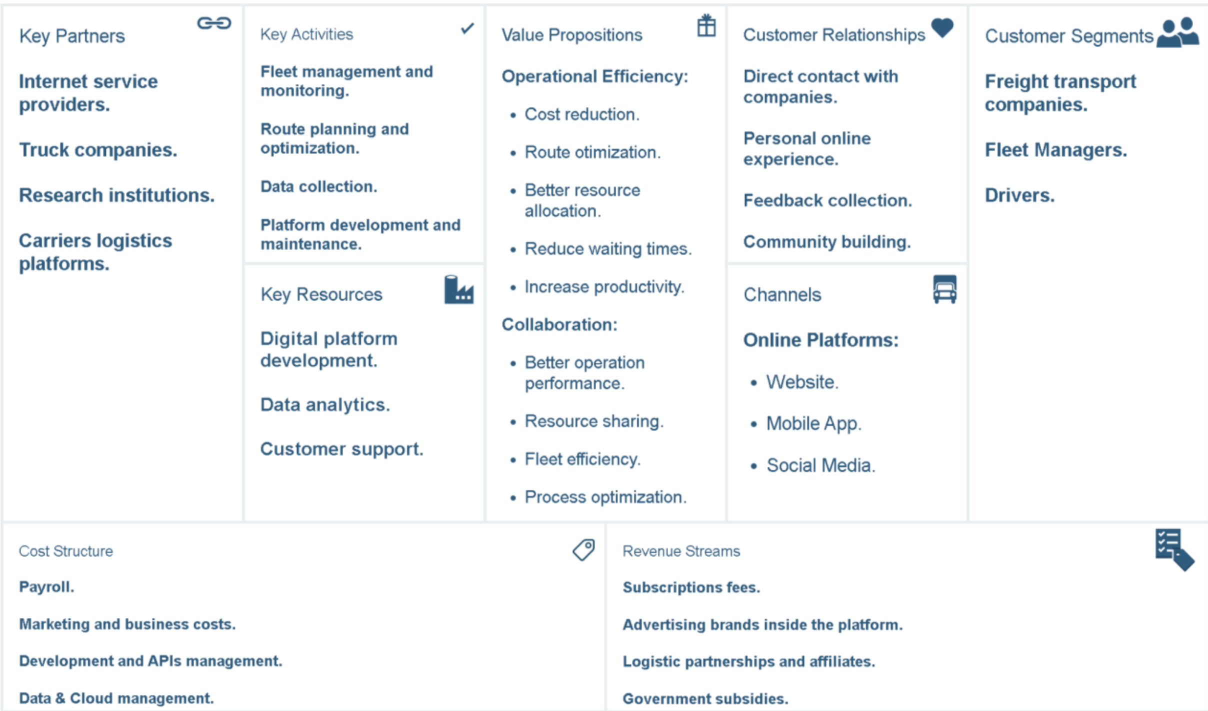


Figure 4.1: Proposed Business Model Canvas for Truck Platooning Application.

Figure 4.1., represents the proposed BMC for the new Truck Platooning application, which determines how each element of the model contributes to the system, as follows:

- **Key Partners:** They are critical to maintaining the application functioning and ensuring the improvement of our system. For instance, the **Internet Service Providers** will provide the connectivity required for real-time data sharing and communication between trucks and the companies assistants. Furthermore, **Truck Companies** are the perfect match for us to test different scenarios, as well as access to skilled drivers. Also, **Research Institutions** collaboration helps to promote new initiatives for more efficiency and safety insights. Finally, **Carriers Logistics Platforms** provide the expansion of our application promoting integration into existing logistics platforms, so we can create new solutions for the system.

- **Key Activities:** The model is based on four main activities, such as **Data Collection**, **Route Planning and Optimization**, **Fleet Management and Monitoring** and **Platform Development and Maintenance**. For example, to enhance efficiency and safety, fleet management and monitoring continually track the position and status of every truck. Also, together with research partners, the service providers will cooperate to build planning algorithms to optimize routes to lower fuel consumption and travel time, which will be supported by the data collection received from the truck devices, and last, the platform development and maintenance will make sure that the system is flexible for each user needs.

- **Key Resources:** The primary resources are **Digital Platform Development**, **Data Analytics**, and **Customer Support**. For instance, IS engineers and data scientists can create and manage more digital infrastructures to support the system. Furthermore, data analytics enables amounts of data from the fleets to provide insights to improve operational tasks. Finally, a team from customer support is needed to ensure that any issues experienced can be solved quickly, resulting in high levels of user satisfaction.

- **Value Propositions:** There are two significant value propositions for the system, such as **Operational Efficiency** and **Collaboration**. For example, in operational efficiency, the system must guarantee reduced costs, by using less fuel consumption, efficient routes, which reduce delays and improve delivery times, and better resource allocation for more efficient use of vehicles and truck drivers, resulting in increased total production. On the other hand, the collaboration, includes resource sharing across different stakeholders, and fleet efficiency, by enhancing the best use of vehicles. These improvements will result in higher productivity and better daily operations.

- **Customer Relationships:** Customer Relations is a critical factor for the success of the system. Therefore, service providers must cooperate with their customers by establishing **Direct Contact with Companies**, to perceive their needs and provide customized solutions. Also, the **Feedback Collection** allows the users to keep improving the system, and lastly, **Building a Community** will create discussion groups where experiences and practices can be shared.

- **Channels:** These are related to **Online Platforms**, such as the system **Website**, **Mobile App** and **Social Media**. For example, the website has full information about all the features, benefits and pricing. The mobile application will allow interaction and communications between the system, fleet managers and drivers while on the road. Social Media will create engagement with users, to promote the system services.

- **Customer Segments:** The target customers include **Freight Transport Companies**, **Fleet Managers** and **Drivers**. The companies will see a decrease in operational costs and an improvement in delivery times. The fleet managers and drivers will optimize logistics operations by using our system.

- **Cost Structure:** Most of the systems costs are represented by **Payroll**, **Marketing and Business Costs**, **Development and APIs Management**, and **Data and Cloud Management** – For instance, the payroll includes any salary for engineers and customer service representatives. The marketing and business costs cover promotional ideas. The development and APIs management cover the maintenance and creation of new ideas costs. Finally, the data and cloud management refer to costs regarding cloud processing or data store.

- **Revenue Streams:** These are related to **Subscriptions**, **Advertising brands**, **Logistics Partnerships and Affiliates**, and **Government Subsidies**. For subscriptions, stakeholders will pay membership fees to generate revenue. Regarding advertising brands inside the platform, additional revenue will be created due to allowing brands to advertise inside the system. For logistics partnerships and affiliates, revenue will be received through collaborative projects. Lastly, government subsidies will help to generate cash to promote clean and efficient transport solutions.

In conclusion, this analysis of BMC is very important to identify areas of improvement as well as ensure the long-term sustainability of our truck platooning system.

4.2 Service Blueprint

Another crucial model for the design of the truck platooning system is represented by the service blueprint framework, as illustrated in APPENDIX D, which is based on the interactions between different stakeholders, including the logistic company assistants, drivers, and the supporting processes necessary for the system success. Therefore, the model consists of: the drivers that control the vehicles and assist in the digital platform operations, the logistic company assistant who monitors and provides information to the drivers from the office, the frontage and backstage actions, and the supporting processes of the digital platform system, explained as follows:

- **Logistic Company Assistant tasks:** Backoffice assistants, that remain in the logistics companies offices, are responsible for managing and coordinating the entire platooning operations. They are the ones planning delivery times, routes, and others crucial operation tasks. Initially, they handle the registration forms and give the drivers the credentials to access the whole system. Also, are in charge of starting, updating and deleting transport bookings or requests as necessary. Once completed, they look for the platoon formations and release, organizing real-time activities to guarantee scheduled departures and arrivals. Furthermore, they will assist in any issue ticket for any driver matter and lastly, they take care of any invoice or expenses to precisely ensure that all financial questions are in due time.

- **Driver Actions:** Drivers must insert the given credentials by the logistic company assistant and then log in to the system. After that, they should look for open job positions and double-check if the requests have the same specifications as their cargo, such as location, weight, and description. Also, they can create, join or leave platoons as needed according to the requirements of the moment. Furthermore, if any issues cannot be solved, they must interact with the backoffice assistants to guarantee efficient communication and problem-solving, finally, drivers should provide feedback and reviews once the platoon is finalized, so the system can be continuously improved based on their experiences.

- **Frontstage Actions:** Registration and authentication are the first procedure, which provides credentials to open the whole system. **<u>These actions are performed by the driver support (depending on the company, it can be the system or a driver assistant).</u>** Then, the system verifies the data information and uses real-time data to group vehicles into platoons to organize fleet formations. Furthermore, notifications are sent to drivers regarding information about jobs and platoon status. Also, the system monitors and tracks data about the condition of the vehicles as well as its management for efficient running, finally, invoices and payments are shown by the system from all the services provided.

- **Backstage Actions:** Database management guarantees that all the data is stored while guaranteeing information integrity and availability. Furthermore, the system provides route optimization and allocates the drivers to ensure that platoons are grouped correctly and efficiently according to the information provided by the system. Also, real-time communication is enabled between drivers and the logistic company assistant. Then, each trip is monitored to ensure that follows the schedules and plans, and lastly, the system calculates costs and benefits by analyzing financial reports of all elements in the platooning.

- **Supporting Processes:** Maintenance is one of the core processes which makes sure that all system operates, and technical issues are addressed quickly. Thus, integration makes all operations run properly, and the issue alerts allow problem resolution smoothly by providing timely notifications when problems arise.

According to Bitner et al., (2008) the detailed process mapping provided by this blueprint ensures the understanding of real-world operations, by highlighting interactions and dependencies for a comprehensive implementation. Thus, the model was designed according to theoretical models but also was confirmed with a few experts in the truck industry area, with some important insights, which were incorporated into the final design, as explained in the above chapter from the research methodology. Since this system is fully digital, physical evidences were removed, because there are no tangible resources.

4.3 Business Processes Mapping

The first step of our application is defined by managing the registration form, where the logistic company assistant downloads and installs the application, opens it and inserts the user credentials. If they were not created already, the user must submit the new form, by validating the necessary information and all data is stored in the internal database for accurate and complete user data, as illustrated in Figure 4.2.

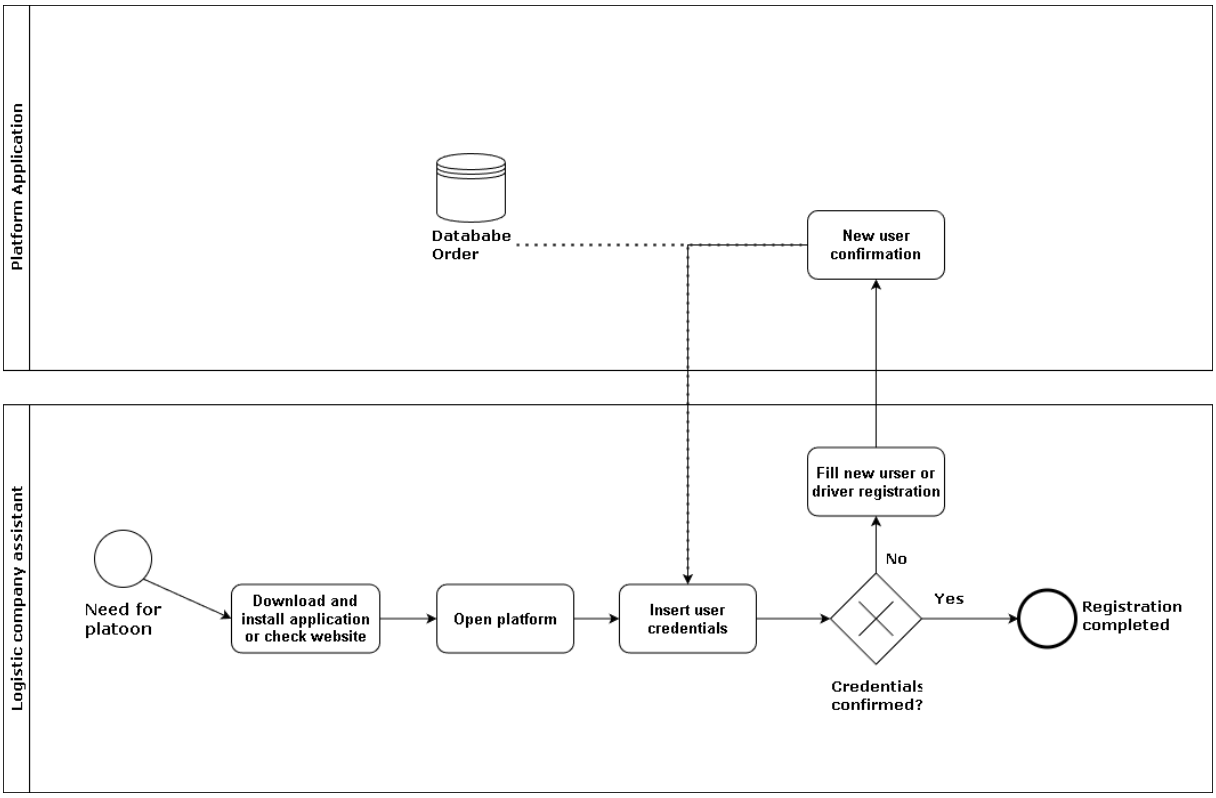


Figure 4.2: Managing Registration Form from the truck platooning system.

As soon as the registration is completed, the next phase is to make sure that all services are unlocked, by choosing the best subscription plan that is aligned with the customer needs. If the subscription is already done, the logistic company assistant can start new requests for platooning operations, however, if the subscription is not completed, a request is sent to the system that generates a new invoice and sent to the logistics company to be payable in due time. Then, the company should check if the expenses are correct and approve the invoice by confirming the payment, as shown in Figure 4.3.

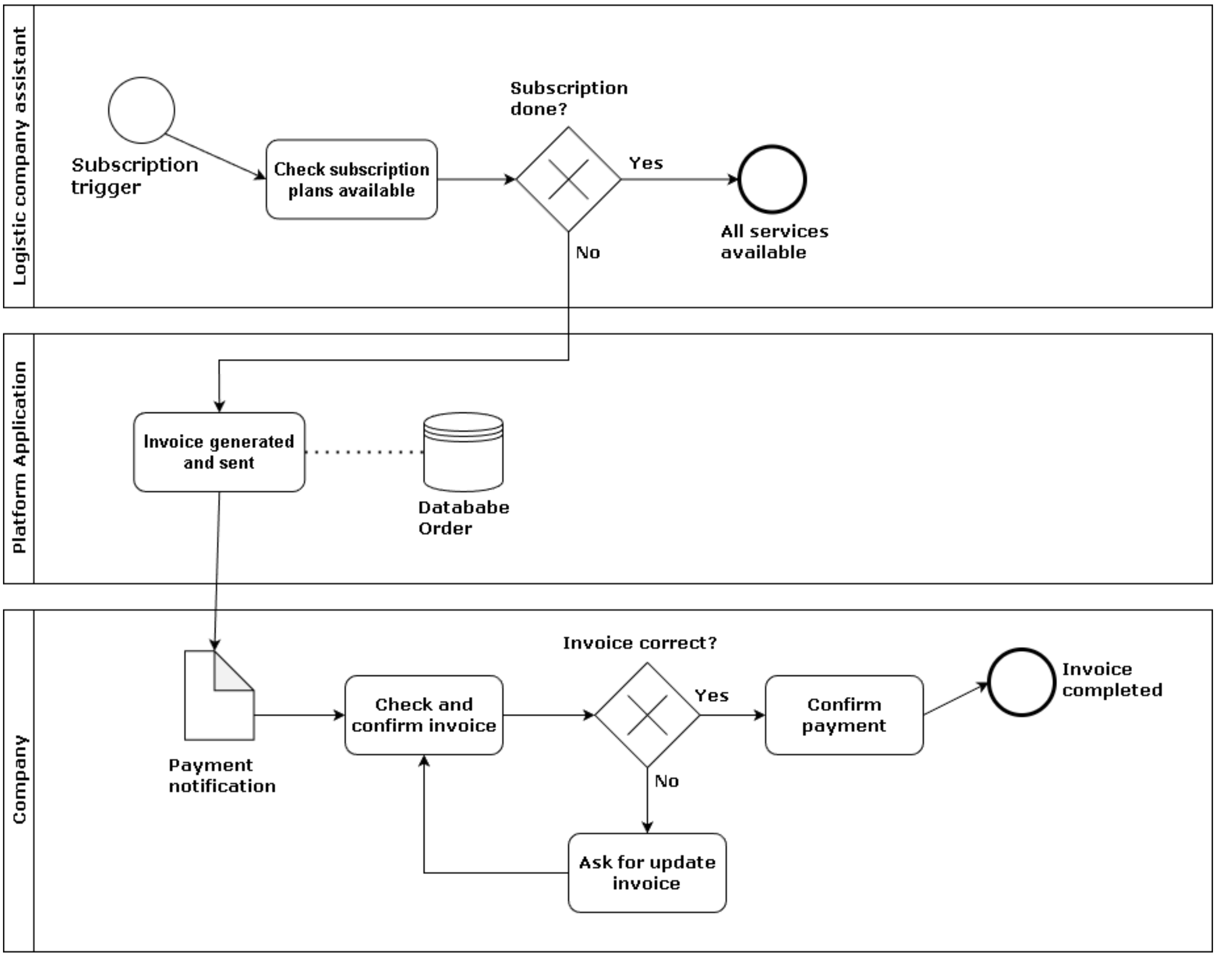


Figure 4.3: Subscription plans regarding the truck platooning system.

Once the subscription payment is approved by the system, services are now authorized for those accounts approved. Therefore, the system is divided into three use case scenarios, such as the creation of platoons within the same company, the request for platoons between different companies, but the system is responsible for combining according to the information received, and finally, another scenario where the truck driver watches platoons on a highway and submits to the system a new booking request with the proper documentation to check by the system if it is possible to join or not. So, these scenarios are described as follows:

- **The first use case for platoon request (same company):** According to APPENDIX E, the process starts with an order request by the logistic company assistant, including cargo details, such as destination, cargo description, weight and other pertinent details. Then, the drivers and vehicle types are assigned to the order. Also, if an update request is received, the order must be adjusted, or if a cancellation is required the booking is deleted from the system. On the other hand, once the booking confirmation is sent from the application, truck drivers insert the credentials after installing the application. After logging in, they should check for open jobs and identify the specifications of the request, by confirming vehicle type as well as car registration. If the confirmation is not done by the driver, the order is cancelled, and the logistic company assistant is notified. However, when the driver confirms the job, the system checks the driver's work hours and the legal rest history, but if this information does not comply with the legal terms, the logistic company assistant is also notified, and the order is cancelled. If drivers comply, the system ensures that the best path is optimized and sends all the information to the driver required to generate a new platoon formation. Then, the truck driver loads the truck and manually goes to the nearest highway platoon formation point, informed by the booking details. Once the arrival of the platoons, they merge, and the system notifies the logistic company assistant, indicating the successful merging.

- **The second use case for platoon request (different companies):** Based on APPENDIX F, when the logistic company assistant has an order request, they can check prior if any other customer has platoons pending status inside the queue, so they can understand if there is any suitable platoon found. Without any record found inside the queue, the logistic company assistant creates a new order request in the system, defining the cargo name and weight as well as assigning the available drivers and vehicle type. With all details considered and submitted, the order request is sent through the platform application. Also, if an update request is received, the order must be adjusted, or if a cancellation is required the booking is deleted from the system. As soon as the booking confirmation is sent to the driver, they log in by inserting their credentials, to gain access to the functionalities. Then, check for open jobs and review the details, ensuring that all information aligns with the order request. Once confirmation is done, the driver should also verify the vehicle type and registration, however, if they were not approved the status remains pending. When confirmation is received by the driver, the system checks his legal work hours and the rest history. As soon as this step is confirmed the system proceeds to check if there are other drivers in the queue for platooning, however, if they do not comply with those legal criteria, the booking is cancelled. If other drivers are in the queue, the algorithm holds until the required number of vehicles is reached and optimizes the route for the entire platoon. Then, the truck driver loads the truck and manually goes to the nearest highway platoon formation point, informed by the booking details. Once the arrival of the platoons, they merge, and the system notifies the logistic company assistant, indicating the successful merging.

- **The third use case for platoon request (On-the-fly):** As highlighted in APPENDIX G, the driver identifies a highway platoon and recognizes the opportunity to join, opens the application, and logs in with their credentials. Once logged in, the driver requests to join the fleet by providing the necessary documentation to identify that possibility. As soon as the system approves the request, a message is sent to the logistic company assistant to confirm all the details submitted by the truck driver and approve the booking request pending on the system. Then, the system checks for the transport guide issued, the legal work and rest hours, if the route is identical and weight compatibility. Once all checks are completed, a notification to join the platoon is sent to the driver and the logistic company assistant, and the driver can merge the truck on the ongoing highway platoon, however, if it does not comply with all checks, the request is immediately rejected.

Depending on the decision made by the logistic company assistant or the driver, after the cargo fleet merges, the system assists in the ongoing phase operation between the parties involved to support if any problem occurs. Therefore, according to Figure 4.4, the process starts with the platoon's initiation, where the truck driver checks the progress to ensure that everything runs well. If no problems arise, the platoon proceeds to the split destination informed by the system, where the cargo fleet is divided, however, if a difficulty occurs during the path, the driver opens a support ticket inside the system. When the ticket is submitted, the platform application adds a new entry and notifies the logistic company assistant. Then, the logistic company assistant receives the notification and checks all the order information to solve the issue. After that, the truck driver is contacted to try to address the issue quickly, however, if the issue can be fixed, the assistant marks it as approved, and the process is completed. If the problem persists, the assistant escalates to the company, to get assistance and approve the ticket.

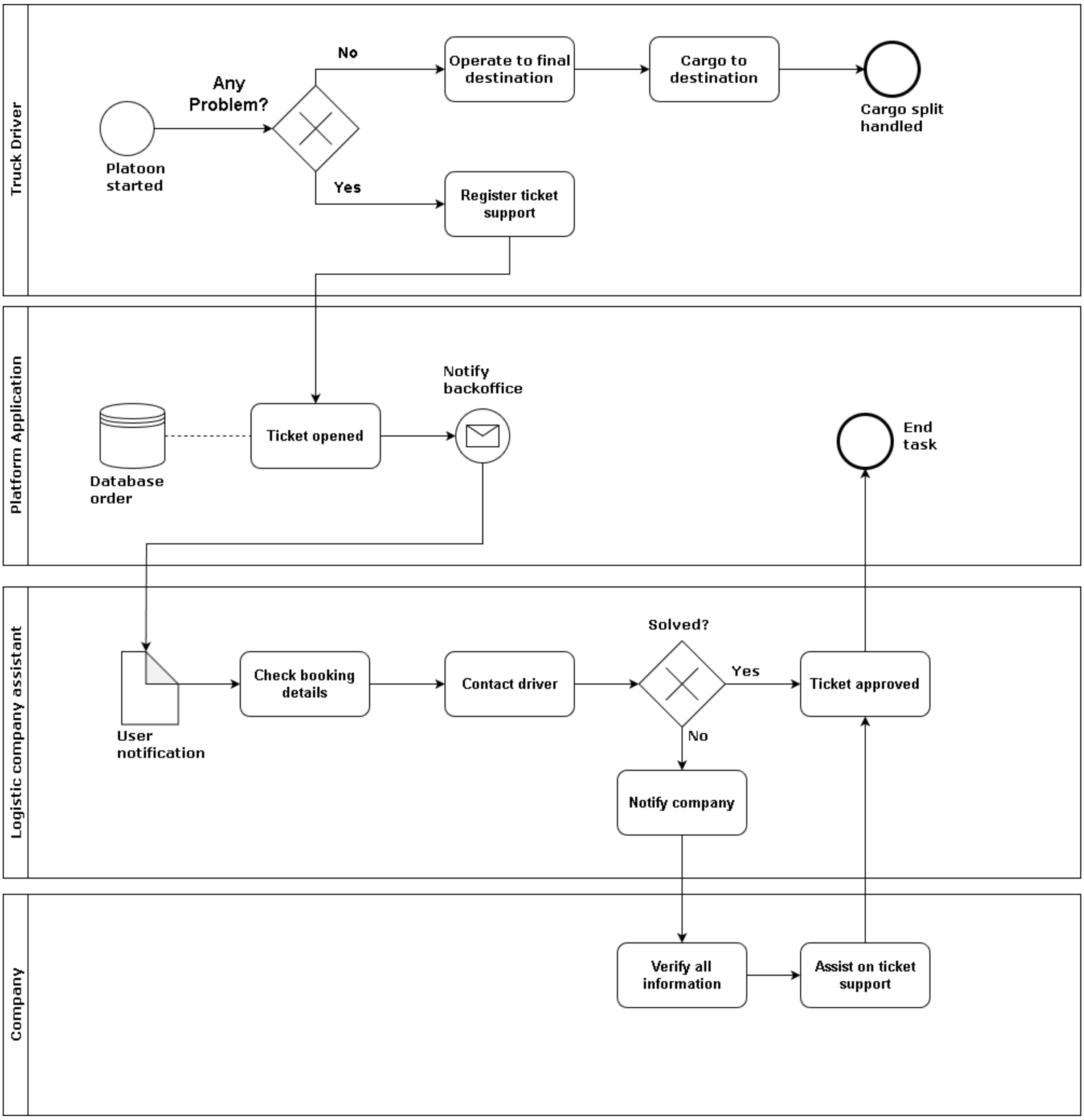


Figure 4.4: Ongoing phase regarding the truck platooning system.

Finally, the last part of the system process mapping is the cost-splitting phase, highlighted in APPENDIX H. When the drivers confirm, inside the application, the conclusion of the platoon, they should rate the journey and review it by offering some comments, to support the platooning system's ongoing development. After that, the platform marks the order as concluded, and the system calculates the costs per trip, by evaluating the vehicle type. Then, the system determines the benefits based on whether the driver was a leader on the last platoons. If not, a breakdown of all costs is displayed immediately, and an invoice is generated and stored in the internal database. Furthermore, the applications notify the company of payment, and the company must check and approve the invoice, which should be paid in due time, or ask for an update to the system.

These steps ensure that all financial transactions maintain the integrity and efficiency of the overall truck platooning system.

4.4 User & System Requirements

This chapter presents the user and system requirements, according to APPENDIX I & APPENDIX J diagrams, to understand the necessary functionalities and interactions between the driver, the logistic company assistant, and the system application.

The user requirements are divided between the driver and the logistic company assistant. For the driver's requirements, four main categories are considered:

- **User credentials:** The driver must insert the user credentials given by the logistic company assistant and confirm it by email. Thus, they check available jobs for platoon trips inserted into the system.
- **Trip management:** This involves confirming job details and receiving real-time notifications for any changes or issues that might arise.
- **Platoon formation:** The driver must be able to start, join, or form new platoons, which interacts with the logistic company assistant information, ensuring that platoons operate smoothly and efficiently.
- **Notifications:** This includes reviews and feedback, that will evaluate trips, providing insights for the system development.

For the logistic company assistant, the requirements are divided into six categories, including system access, platoon management, invoice and payments, notifications, data verifications and tracking and monitoring, described as follows:

- **System access:** The logistic company assistant fills out the registration form, opens the platform, enters the user credentials, and creates, edits and deletes transport requests for an accurate record of all operations.
- **Platoon Management:** This involves coordinating the formation and release of platoons, monitoring queues present in the system, and checking orders in real-time.
- **Invoice and Payments:** This covers the trips and subscription payments, receiving and storing invoices as well as informing any additional fee to maintain the financial records.
- **Notifications:** This includes payment reminders, checking delivery problems and maintaining real-time communication between the logistic company assistant and the drivers.
- **Data verification:** Ensures the accurate data of the platoon orders, tickets support revision and driver problem-solving.

- **Tracking and Monitoring:** The logistic company assistant monitors the travel status and ensures compliance with regulations.

On the other hand, the system requirements diagram was defined to provide the necessary functionalities for the successful implementation and operation of the truck platoon system and is divided into seven main categories, such as registration and authentication, security, platoon management, real-time communication, scalability, cost and benefits calculation, and trip monitoring. Each of these is explained as follows:

- **Registration and authentication:** The first step that users must take, to access the system, is to register and enter all the information to set up an account. Then, they should confirm their credentials, to be secured in an internal database. Also, users are provided with tutorials to easily understand and navigate inside the system.
- **Security:** Mitigating threats to the user data is a main objective as a requirement, which ensures that no intrusions and breaches may occur.
- **Platoon management:** This includes platoon creation, management, and confirmation, where drivers are chosen, cargo data is verified, and routes confirmed. Furthermore, the control of the order status and the coordination of the operations are essential to keep accurate records.
- **Real-time communication:** This covers the notifications and communications between drivers and the logistic company assistant, to assist with daily operations, as well as tracking with GPS and route updates.
- **Scalability:** This ensures that the system can manage a high volume of requests, which is essential to support increasing demands and guarantee that the system can expand without affecting functionality. Therefore, as the amount of users and requests grows, the system must be able to scale to maintain stability and responsiveness.
- **Cost and benefits calculation:** The system should generate invoices, notify clients of payments and calculate trip expenses. So, a method for cost-benefit analysis must be offered to assist users in evaluating financial reports of their operations.
- **Trip monitoring:** This ensures that some activities of the platoon journey are stored and monitored, such as the average speed, merge and split calls, and vehicle type tracking. Therefore, users are notified as soon as there are any adjustments or modifications regarding the schedules initially offered.

4.5 Microservices design

Last, as illustrated in APPENDIX K, the microservice architecture diagram was designed to show the system's structure, which is intended to manage and perform multiple tasks efficiently due to independent services. This architecture improves scalability, maintainability and flexibility by separating services into smaller ones, which makes it easier to manage components that execute a specific task.

The API gateway user interface acts as the first point of contact between users and the system, which manages the requests with REST calls from online and mobile users to access the system and interact with the different services. Then, the registration microservice is the initial service of the flow and users can register by confirming their email addresses and completing the registration form, which provides credentials verified through the authentication microservices to guarantee system access. Furthermore, users must handle the subscription microservice by selecting the best suitable plans and payment confirmation, to guarantee access to the proper features and services, by choosing one of the different subscription levels available. After that, all the functionalities of the system are opened and supported by multiple key microservices, explained as follows:

- **Account microservice:** Responsible for managing account details, allowing users to request, manage and update their information.
- **Orders microservice:** Generates new booking requests, and updates and monitors orders at the system.
- **Order management microservice:** Provides resource allocation, route planning and driver management, ensuring that resources are efficiently managed, and routes are planned to fulfil user needs.
- **Costs microservice:** Calculates costs-benefits, providing financial analysis with structured reports to help users better understand their operations.
- **Notifications microservice:** Handles payment reminders, and booking updates, and sets user preferences for the most important ones as they wish.

Depending on each microservice, those are supplied by its internal database (DB), ensuring the data integrity and isolation of the system. For instance, the user DB secures the integrity of the user credentials, the subscription DB secures the subscription plan fees, and the company DB enables efficient payments. Also, the order and platoons DB store data from the start of the booking until the end, receiving feedback and reviews from the drivers. Furthermore, the costs DB ensures that the charges are stored and provides users with their financial reports and statistics, and the notifications DB allow users to customize update alerts as they wish.

On the other hand, the system will rely on cloud services and storage to host and manage the data and services. This leads to better scalability and adaptability, guaranteeing that the system can support and manage the changes in traffic and user demands correctly.

5 Conclusion

The analysis of this dissertation was to understand the subject of truck platooning and its current state of the art, where different business models were drawn to design a new service proposition, supported by a conceptual digital platform for the truck logistics industry. Thus, the system presented in this work aims to enrich the user experience, creating impact and value for the topic and future research, where different stakeholders can share their resources and split costs on their daily operations. As highlighted by Axelsson (2019), a third-party entity could manage the services independently, resulting in a centralized solution for the TP ecosystem. Moreover, based on Kagennar & Mingardo (2016), a suggestion was made to create a central digital network, which would facilitate different truck drivers joining together to form platoons, explaining that certain benefits could be shared among all parties involved through this service provider, such as reduced fuel consumption and less drive times in the future. However, this service should not be free, as stakeholders must pay a fee to join the network, which may discourage some participants, although a big pool of participants will allow the future success of the service provider.

This study was elaborated based on literature review, as well as one face-to-face interview with a truck logistic company, called Luís Simões Logística. This allowed to understand and analyze the potential of truck platooning and their business perspectives. One important model presented at the time of the interview was the development of the business model canvas, which gave new ideas on how to improve and refine the digital platform system, outlining all the relationships between stakeholders, the goals to be achieved and the future business strategies.

As a result of the research, the main conclusion established is that there is a huge challenge towards the future adoption and implementation of truck platooning technologies that arise due to limited understanding and awareness by the people who were interviewed. Also, managers and assistant from the logistic companies in the industry tend to avoid giving truck drivers too much responsibility when it comes to planning daily operations, and so this fact poses a substantial barrier for them to interact with the digital platform, without receiving orders from their headquarters managers and assistants.

Moreover, truck platooning presents limitations on planning formation, since limits its use to highways so that merging and splitting may be done securely (Marzano et al., 2022). Due to these conditions, it's not viable on normal roads, which drastically reduces its operational range and performance. Furthermore, the current level of vehicle automation is an important consideration in future implementation. At the moment, truck platooning operates at SAE’s level 2, requiring drivers direction and observation (Simoes et al., 2022), so it makes platoon operations more complicated and would be necessary to go to higher levels to achieve the full benefits of platooning, such as improved efficiency and safety.

Finally, the research was limited and conditioned by the number of interviews that were conducted, since only one company took part in the interview process and others did not respond, therefore there is a small amount of data that serves as a basis for the conclusions.

5.1 Future Research

To maximize its adoption and potential, we need to understand more about the topic, however, some concerns still need to be solved. Future research must focus on certain important topics to address the issues this study raised.

First, the knowledge gap about truck platooning among truck logistic companies needs to be filled by encouraging educational measures between stakeholders, through industry workshops, information campaigns and academic research collaboration. Also, it is crucial to interact with more truck industry managers and assistants, and more companies should be included in future research to collect wider viewpoints and perspectives, build trust and demonstrate safety with simulators or real-world testing to reduce organizational worries. Furthermore, since truck platooning can only be conducted on highways, it is essential to learn more about the rules and infrastructure required to support it on regular roads to enhance truck platooning's operational capabilities.

Second, it is essential to increase the levels of autonomy to higher levels, which would enable truck vehicles to be more capable of facing difficult driving situations with minimal assistance from the driver. Therefore, the conceptual digital platform of this research would be more autonomous and independent of responsibilities as well, ensuring a more secure and scalable system, for real-world scenarios.

Finally, research should continue to improve and confirm the business models brought by this study with many more industry customers, as well as testing with real companies to see if it performs well for the successful implementation of this conceptual system.

References

Aarts, L., & Feddes, G. (2016, November). European truck platooning challenge. In Proceedings of the HVTT14: International Symposium on Heavy Vehicle Transport Technology, Rotorua, New Zealand (pp. 15-18).

Abdolmaleki, M., Shahabi, M., Yin, Y., & Masoud, N. (2021). Itinerary planning for cooperative truck platooning. Transportation Research Part B: Methodological, 153, 91-110.

Amanullah, A. N. A. A., Aziz, N. F. A., Hadi, F. N. H. A. H., & Ibrahim, J. (2015). Comparison of Business Model Canvas (BMC) among the three consulting companies. International Journal of Computer Science and Information Technology Research, 3(2), 462-471.

Axelsson, J. (2019, May). Business models and roles for mediating services in a truck platooning system-of-systems. In 2019 14th Annual Conference System of Systems Engineering (SoSE) (pp. 113-118). IEEE.

Balador, A., Bazzi, A., Hernandez-Jayo, U., de la Iglesia, I., & Ahmadvand, H. (2022). A survey on vehicular communication for cooperative truck platooning application. Vehicular Communications, 35, 100460.

Barua, L., Zou, B., & Choobchian, P. (2023). Maximizing truck platooning participation with preferences. Transportation Research Part E: Logistics and Transportation Review, 179, 103297.

Bitner, M. J., Ostrom, A. L., & Morgan, F. N. (2008). Service blueprinting: a practical technique for service innovation. California management review, 50(3), 66-94.

Bhoopalam, A. K., Agatz, N., & Zuidwijk, R. (2018). Planning of truck platoons: A literature review and directions for future research. Transportation research part B: methodological, 107, 212-228.

Bouchery, Y., Hezarkhani, B., & Stauffer, G. (2022). Coalition formation and cost sharing for truck platooning. Transportation Research Part B: Methodological, 165, 15-34.

Callefi, M. H. B. M., Ganga, G. M. D., Godinho Filho, M., Queiroz, M. M., Reis, V., & dos Reis, J. G. M. (2022). Technology-enabled capabilities in road freight transportation systems: A multi-method study. Expert Systems with Applications, 203, 117497.

Calvert, S. C., Schakel, W. J., & van Arem, B. (2019). Evaluation and modelling of the traffic flow effects of truck platooning. Transportation research part C: emerging technologies, 105, 1-22.

Chen, L. (2023). Analysis of Online Platforms' Free Trial Strategies for Digital Content Subscription. Journal of Theoretical and Applied Electronic Commerce Research, 18(4), 2107-2124.

Chinosi, M., & Trombetta, A. (2012). BPMN: An introduction to the standard. Computer Standards & Interfaces, 34(1), 124-134.

Cleven, A., Gubler, P., & Hüner, K. M. (2009, May). Design alternatives for the evaluation of design science research artifacts. In Proceedings of the 4th International Conference on Design Science Research in Information Systems and Technology (pp. 1-8).

Dekhne, A., Hastings, G., Murnane, J., & Neuhaus, F. (2019). Automation in logistics: Big opportunity, bigger uncertainty. McKinsey Q, 24.

Duarte, S. P., Cunha, L., Ferreira, S., & Lobo, A. (2023). Understanding interdependencies of success factors for truck platooning implementation: a facilitators' perspective. In ICDSST 2023-9th International Conference on Decision Support System Technology: Decision Support System in an Uncertain World: the Contribution of Digital Twins.

Eilers, S., Mårtensson, J., Pettersson, H., Pillado, M., Gallegos, D., Tobar, M., ... & Adolfson, M. (2015, September). COMPANION--Towards Co-operative Platoon Management of Heavy-Duty Vehicles. In 2015 IEEE 18th International Conference on Intelligent Transportation Systems (pp. 1267-1273). IEEE.

EU rules for working in road transport, (EC) No 561/2006, Retrieved from [https://europa.eu/youreurope/citizens/work/work-abroad/rules-working-road-transport]

EUROSTAT. (2021). Eurostat Database. Retrieved from [https://ec.europa.eu/eurostat/databrowser/view/TRAN_HV_FRTRA/default/table?lang=en]

F. Breidbach, C., Brodie, R., & Hollebeek, L. (2014). Beyond virtuality: from engagement platforms to engagement ecosystems. Managing Service Quality, 24(6), 592-611.

Fritz, H. (1999, August). Longitudinal and lateral control of heavy duty trucks for automated vehicle following in mixed traffic: experimental results from the CHAUFFEUR project. In

Proceedings of the 1999 IEEE International Conference on Control Applications (Cat. No. 99CH36328) (Vol. 2, pp. 1348-1352). IEEE.

Giao, J., Nazarenko, A. A., Luis-Ferreira, F., Gonçalves, D., & Sarraipa, J. (2022). A Framework for Service-Oriented Architecture (SOA)-Based IoT Application Development. Processes, 10(9), 1782.

Gregor, S., & Hevner, A. R. (2013). Positioning and presenting design science research for maximum impact. MIS quarterly, 337-355.

Grenha Teixeira, J., Patrício, L., Huang, K. H., Fisk, R. P., Nóbrega, L., & Constantine, L. (2017). The MINDS method: integrating management and interaction design perspectives for service design. Journal of Service Research, 20(3), 240-258.

Gupta, P., Mokal, T. P., Shah, D. D., & Satyanarayana, K. V. V. (2018). Event-driven SOA-based IoT architecture. In International Conference on Intelligent Computing and Applications: ICICA 2016 (pp. 247-258). Springer Singapore.

Hakak, S., Gadekallu, T. R., Maddikunta, P. K. R., Ramu, S. P., Parimala, M., De Alwis, C., & Liyanage, M. (2023). Autonomous Vehicles in 5G and Beyond: A Survey. Vehicular Communications, 39, 100551.

Hevner, A. R. (2007). A three-cycle view of design science research. Scandinavian journal of information systems, 19(2), 4.

Hofmann, E., Sternberg, H., Chen, H., Pflaum, A., & Prockl, G. (2019). Supply chain management and Industry 4.0: conducting research in the digital age. International Journal of Physical Distribution & Logistics Management, 49(10), 945-955.

Jacob, B., & de Chalendar, O. A. (2018). Truck platooning: Expected benefits and implementation conditions on highways. In Heavy Vehicle Transport Technology (HVTT) International Symposium.

Janssen, R., Zwijnenberg, H., Blankers, I., & de Kruijff, J. (2015). Truck platooning. Driving the.

Kagenaar, S., & Mingardo, G. (2016). The network effects of truck platooning: A case study analysis focusing on.

Kiani Mavi, R., Kiani Mavi, N., Olaru, D., Biermann, S., & Chi, S. (2022). Innovations in freight transport: A systematic literature evaluation and COVID implications. The International Journal of Logistics Management, 33(4), 1157-1195.

Kim, E., Kim, Y., & Park, J. (2022). The necessity of introducing autonomous trucks in logistics 4.0. Sustainability, 14(7), 3978.

Knoche, H. (2016, March). Sustaining runtime performance while incrementally modernizing transactional monolithic software towards microservices. In Proceedings of the 7th ACM/SPEC on International Conference on Performance Engineering (pp. 121-124).

Konstantinopoulou, L., Coda, A., & Schmidt, F. (2019, May). Specifications for multi-brand truck platooning. In ICWIM 8, 8th International Conference on Weigh-In-Motion (pp. 8-p).

Kostopoulos, G., Gounaris, S., & Boukis, A. (2012). Service blueprinting effectiveness: drivers of success. Managing Service Quality: An International Journal, 22(6), 580-591.

Kübler, R., Seifert, R., & Kandziora, M. (2021). Content valuation strategies for digital subscription platforms. Journal of cultural economics, 45, 295-326.

Kukla-Gryz, A., Tyrowicz, J., & Krawczyk, M. (2021). Digital piracy and the perception of price fairness: evidence from a field experiment. Journal of Cultural Economics, 45, 105-131.

Lank, C., Haberstroh, M., & Wille, M. (2011). Interaction of human, machine, and environment in automated driving systems. Transportation research record, 2243(1), 138-145.

Larsen, R., Rich, J., & Rasmussen, T. K. (2019). Hub-based truck platooning: Potentials and profitability. Transportation Research Part E: Logistics and Transportation Review, 127, 249-264.

Lee, Y., Ahn, T., Lee, C., Kim, S., & Park, K. (2020). A novel path planning algorithm for truck platooning using V2V communication. Sensors, 20(24), 7022.

Lesch, V., Breitbach, M., Segata, M., Becker, C., Kounev, S., & Krupitzer, C. (2021). An overview on approaches for coordination of platoons. IEEE Transactions on Intelligent Transportation Systems, 23(8), 10049-10065.

Liu, G., Huang, B., Liang, Z., Qin, M., Zhou, H., & Li, Z. (2020, December). Microservices: architecture, container, and challenges. In 2020 IEEE 20th international conference on software quality, reliability and security companion (QRS-C) (pp. 629-635). IEEE.

Liu, Y., Cai, Z., & Dou, H. (2023). Highway traffic congestion detection and evaluation based on deep learning techniques. Soft Computing, 27(17), 12249-12265.

Lourenço, V., Duarte, S. P., Lobo, A., Ferreira, S., & Cunha, L. (2024). Representations of truck platooning acceptance of truck drivers, decision-makers, and general public: A systematic review. Transportation Research Part F: Traffic Psychology and Behaviour, 104, 359-373.

Lu, X. Y., & Shladover, S. E. (2011). Automated truck platoon control.

Maguire, M., & Bevan, N. (2002, August). User requirements analysis: a review of supporting methods. In IFIP World Computer Congress, TC 13 (pp. 133-148). Boston, MA: Springer US.

Marzano, V., Tinessa, F., Fiori, C., Tocchi, D., Papola, A., Aponte, D., ... & Simonelli, F. (2022). Impacts of truck platooning on the multimodal freight transport market: An exploratory assessment on a case study in Italy. Transportation Research Part A: Policy and Practice, 163, 100-125.

Mascalchi, E., Coda, A., & Willemsen, D. (2020). Specifications for multi-brand truck platooning. 8th Transport Research Arena TRA 2020, April 27, 30.

Mateus-Coelho, N., Cruz-Cunha, M., & Ferreira, L. G. (2021). Security in microservices architectures. Procedia Computer Science, 181, 1225-1236.

Mathew, S., & Varia, J. (2014). Overview of amazon web services. Amazon Whitepapers, 105(1), 22.

Milton, S. K., & Johnson, L. W. (2012). Service blueprinting and BPMN: a comparison. Managing Service Quality: An International Journal, 22(6), 606-621.

Mumford, E. (1985). Defining system requirements to meet business needs: a case study example. The Computer Journal, 28(2), 97-104.

Neto, C., Simões, A., & Lobo, A. (2023). Communication Needs and the Driver's Activity in Platooning Systems. In Human Factors in Transportation-Proceedings of the 14th International Conference on Applied Human Factors and Ergonomics and the Affiliated Conferences.

Neubauer, M., Schauer, O., & Schildorfer, W. (2020). A scenario-based investigation of truck platooning acceptance. In Advances in Human Factors of Transportation: Proceedings of the

AHFE 2019 International Conference on Human Factors in Transportation, July 24-28, 2019, Washington DC, USA 10 (pp. 453-461). Springer International Publishing.

Nowakowski, C., Shladover, S. E., Lu, X. Y., Thompson, D., & Kailas, A. (2015). Cooperative adaptive cruise control (CACC) for truck platooning: Operational concept alternatives.

Osterwalder, A., & Pigneur, Y. (2011). Aligning profit and purpose through business model innovation. Responsible management practices for the 21st century, 61-76.

Owen, M., & Raj, J. (2003). BPMN and business process management. Introduction to the new business process modeling standard, 1-27.

Paddeu, D., & Denby, J. (2021). Decarbonizing road freight: Is truck automation and platooning an opportunity?. Clean Technologies and Environmental Policy, 1-15.

Pencheva, E., & Atanasov, I. (2016). Engineering of web services for internet of things applications. Information Systems Frontiers, 18, 277-292.

SAE. (2021). SAE Blog. Retrieved from https://www.sae.org/blog/sae-j3016-update.

Schirrer, A., Gratzer, A. L., Thormann, S., Jakubek, S., Neubauer, M., & Schildorfer, W. (2022). Energy-Efficient and Semi-automated Truck Platooning: Research and Evaluation (p. 237). Springer Nature.

Scholl, J., Boysen, N., & Scholl, A. (2023). E-platooning: Optimizing platoon formation for long-haul transportation with electric commercial vehicles. European Journal of Operational Research, 304(2), 525-542.

Shladover, S. E. (2007). PATH at 20—History and major milestones. IEEE Transactions on Intelligent Transportation Systems, 8(4), 584-592.

Shladover, S., Lu, X. Y., Yang, S., Ramezani, H., Spring, J., Nowakowski, C., & Nelson, D. (2018). Cooperative adaptive cruise control (CACC) for partially automated truck platooning.

Simoes, A., Lobo, A., Ferreira, S., Rodrigues, C., Tavares, J. P., Couto, A., ... & Neto, C. (2022). Mapping Risks and Requirements for Truck Platooning: A Human-Centred Approach. In Human Interaction, Emerging Technologies and Future Systems V: Proceedings of the 5th International Virtual Conference on Human Interaction and Emerging Technologies, IHIET

2021, August 27-29, 2021 and the 6th IHIET: Future Systems (IHIET-FS 2021), October 28-30, 2021, France (pp. 514-522). Springer International Publishing.

Solberg, A. (2022). Truck platooning.

Teixeira, J. G., Patrício, L., & Tuunanen, T. (2019). Advancing service design research with design science research. Journal of Service Management, 30(5), 577-592.

Teixeira, J. G., Patrício, L., & Tuunanen, T. (2018). Bringing design science research to service design. In Exploring Service Science: 9th International Conference, IESS 2018, Karlsruhe, Germany, September 19–21, 2018, Proceedings 9 (pp. 373-384). Springer International Publishing.

Tsugawa, S., Jeschke, S., & Shladover, S. E. (2016). A review of truck platooning projects for energy savings. IEEE Transactions on Intelligent Vehicles, 1(1), 68-77.

Valipour, M. H., AmirZafari, B., Maleki, K. N., & Daneshpour, N. (2009, August). A brief survey of software architecture concepts and service-oriented architecture. In 2009 2nd IEEE International Conference on Computer Science and Information Technology (pp. 34-38). IEEE.

Villamizar, M., Garces, O., Ochoa, L., Castro, H., Salamanca, L., Verano, M., ... & Lang, M. (2016, May). Infrastructure cost comparison of running web applications in the cloud using AWS lambda and monolithic and microservice architectures. In 2016 16th IEEE/ACM International Symposium on Cluster, Cloud and Grid Computing (CCGrid) (pp. 179-182). IEEE.

Weigand, H., Johannesson, P., & Andersson, B. (2021). An artifact ontology for design science research. Data & Knowledge Engineering, 133, 101878.

Willemsen, D. M., Schmeitz, A. J., & Mascalchi, E. (2023). EU ENSEMBLE Project: Specification of an interoperable solution for a support function for platooning. IEEE Transactions on Intelligent Transportation Systems.

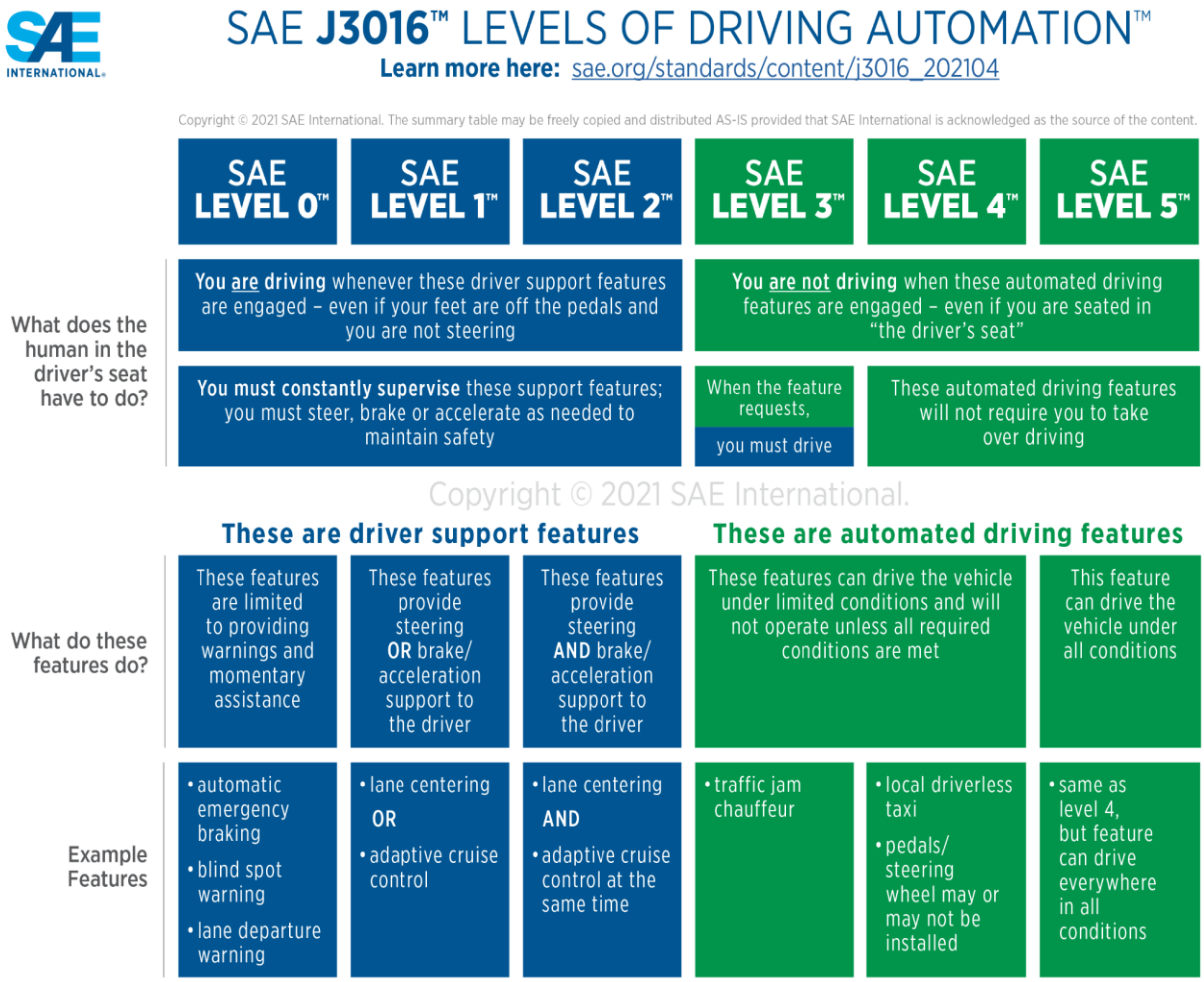
Won, M. (2021). L-Platooning: A protocol for managing a long platoon with DSRC. IEEE Transactions on Intelligent Transportation Systems, 23(6), 5777-5790.

Wong, P. Y., & Gibbons, J. (2008, October). A process semantics for BPMN. In International Conference on Formal Engineering Methods (pp. 355-374). Berlin, Heidelberg: Springer Berlin Heidelberg.

Zhang, L., Chen, F., Ma, X., & Pan, X. (2020). Fuel economy in truck platooning: A literature overview and directions for future research. Journal of Advanced Transportation, 2020.

Zhang, L., & Zhang, Y. (2024). Whether to Add a Digital Product into Subscription Service?. Journal of Theoretical and Applied Electronic Commerce Research, 19(2), 921-941.

APPENDIX A: SAE Automation Levels



APPENDIX B: Qualitative Interview Structure (Part One)

Guião p/ Entrevista - Truck Platooning:

Nome da empresa?

Função?

Área de actuação?

Idade?

Conhecimento sobre o assunto:

- Qual o seu nível de familiaridade com este tema, por favor?

"Escala de Likert - (5 valores): 1 – Nenhum conhecimento, 2 – Conhecimento Básico, 3 – Conhecimento intermediário, 4 – Conhecimento avançado, 5 – Experiente no tema."

Aceitação e Implementação:

- Acredita que a construção de uma plataforma de "multi-brand platooning" seria benéfica para o setor rodoviário em Portugal?
    - Porquê?
- Quais as funcionalidades que considera essenciais na construção da mesma?
    - Que requisitos considera essenciais para esta plataforma?
- Esta plataforma poderia facilitar a colaboração entre empresas do setor?
    - Como?

Questões operacionais:

- Como considera que o processo de junção de "platoons" deveria ser realizado para garantir a eficiência operacional e a segurança nas estradas portuguesas?
- Quais são os principais desafios operacionais que antevê na junção de "platoons".
    - Como sugere abordá-los?
- Acredita que a implementação de janelas horárias específicas para a operação de "platoons" seria benéfica?
    - Se sim, que intervalos sugere como mais adequados?

APPENDIX C: Qualitative Interview Structure (Part Two)

Partilha de Custos:

- Quais os custos que considera mais importantes para serem partilhados no contexto do "platoon"?
- Considera a partilha de custos como um aspeto importante para a empresa?
  - Porquê?
- Que critérios deverão ser considerados mais justos e equitativos para ambas as partes na partilha de custos operacionais?

Perspectivas Futuras:

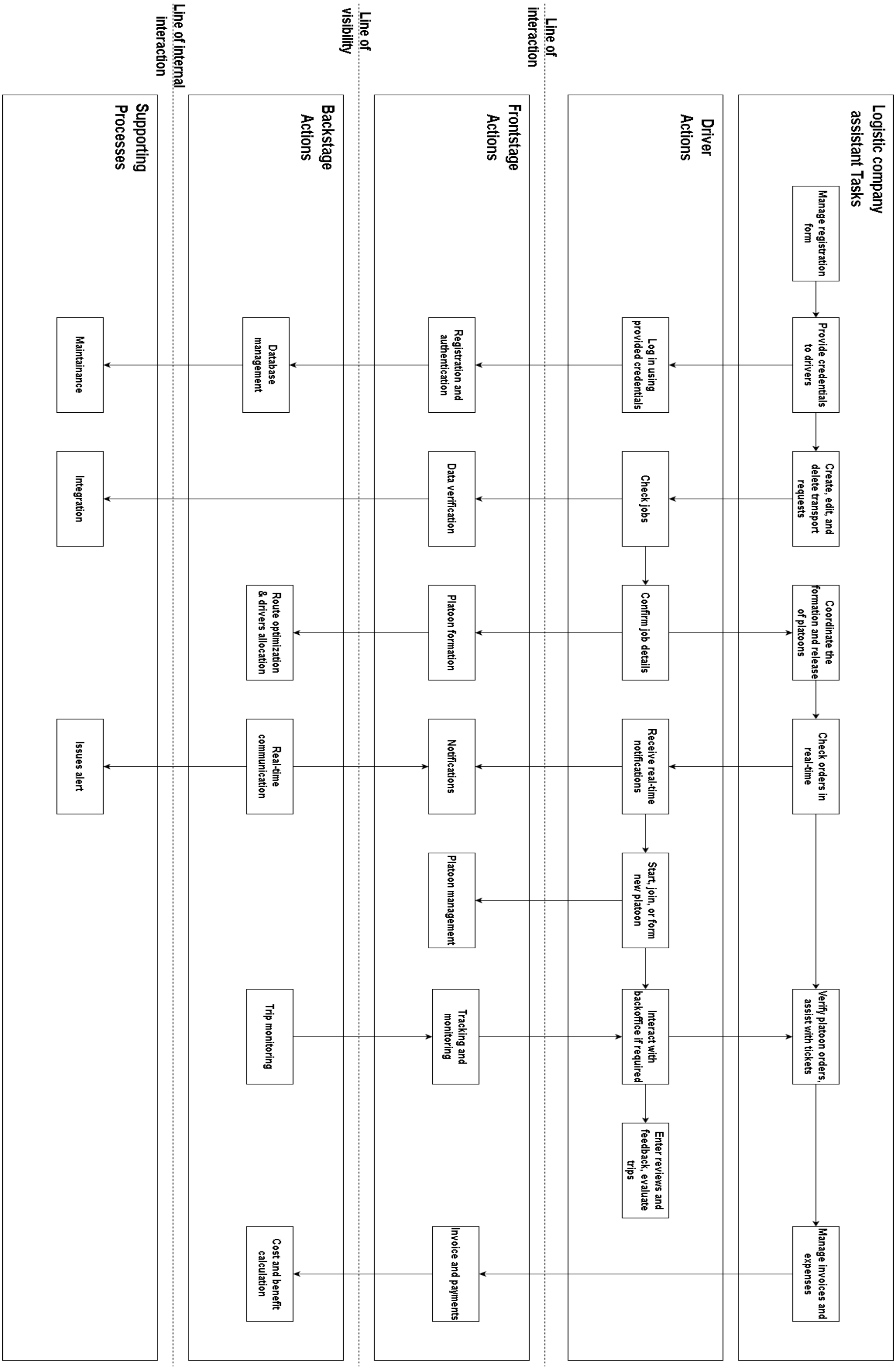
- Acredita que esta plataforma deverá integrar-se aos sistema já em uso nas empresas ou deverá ser independente?
  - Porquê?
- Como acha que a plataforma poderia garantir a confidencialidade dos dados partilhados entre as empresas?
  - Que medidas de segurança sugere para proteger dados sensíveis?
- Deseja que a plataforma de Truck Platooning seja personalizável para satisfazer as necessidades específicas da sua empresa?
  - De que forma imagina essa customização (KPIs, Gestão de Rotas, Relatórios e Análises)?

Para terminar, e com o intuito de enriquecer ainda mais a nossa compreensão sobre o tema, há alguém em particular que sugere incluir neste estudo?

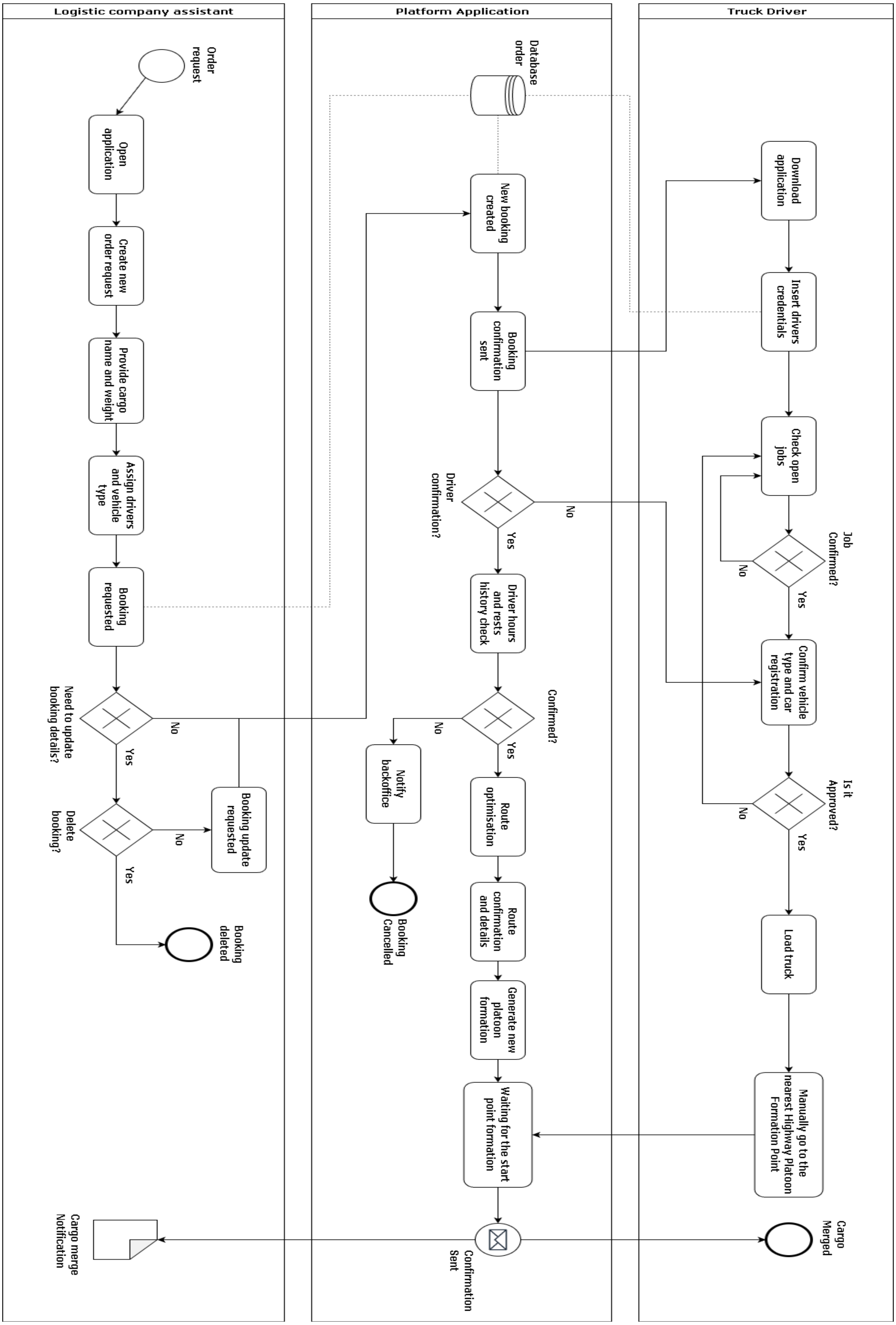
Agradecemos a sua participação nesta entrevista.

Nome: (____) Data: (__/__/____)

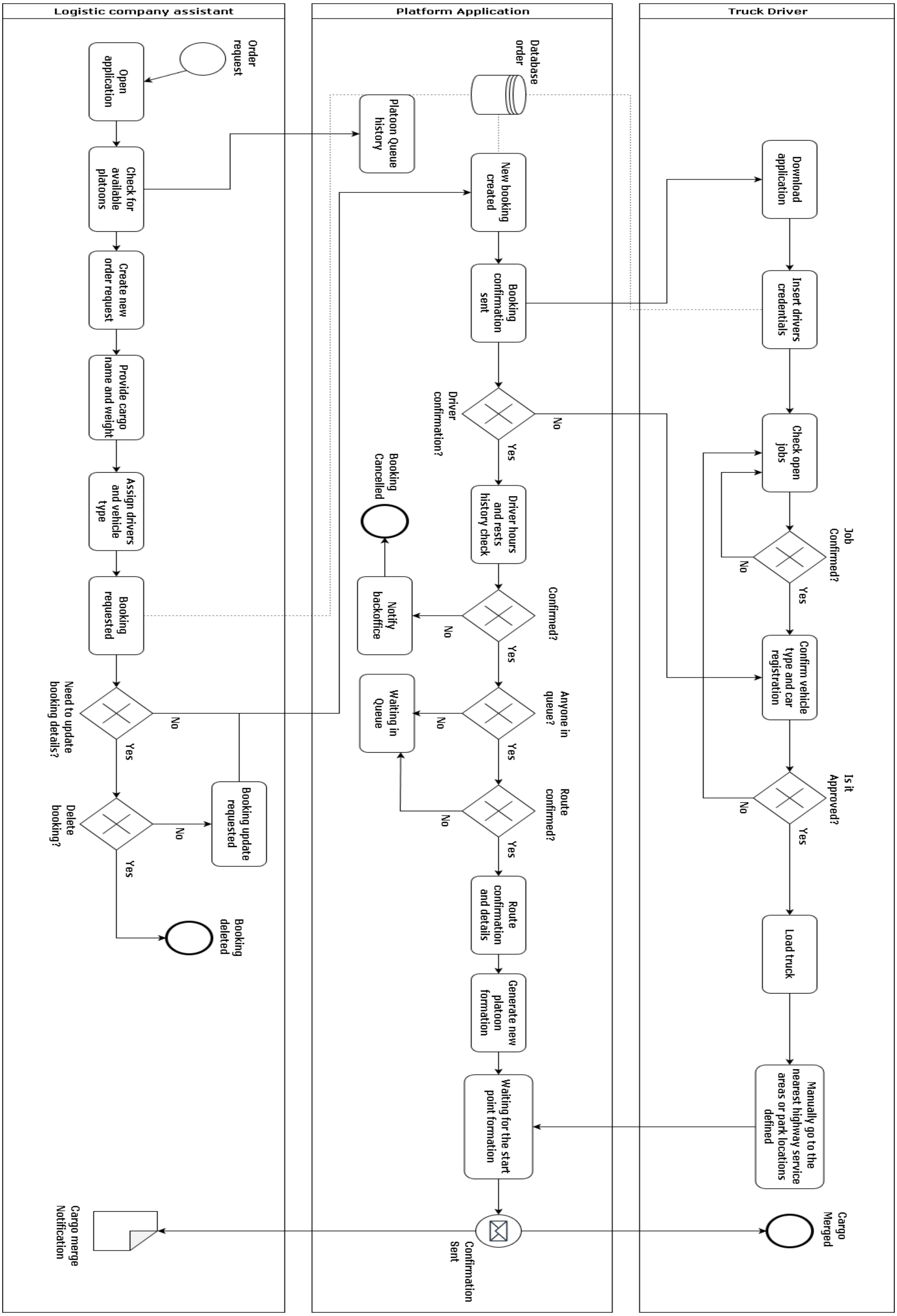
APPENDIX D: Service Blueprint



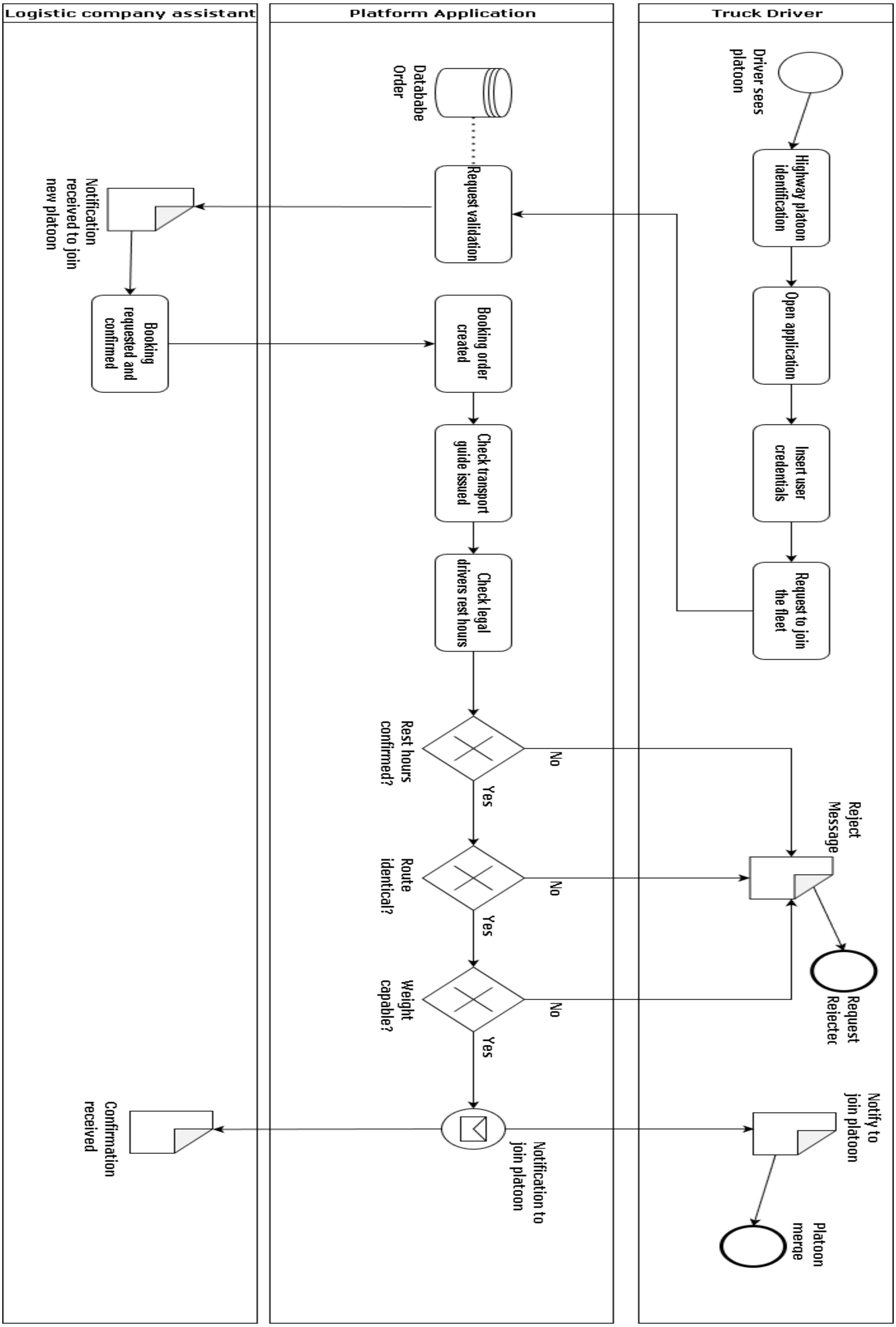
APPENDIX E: First Use Case for Platoon request (Same company)



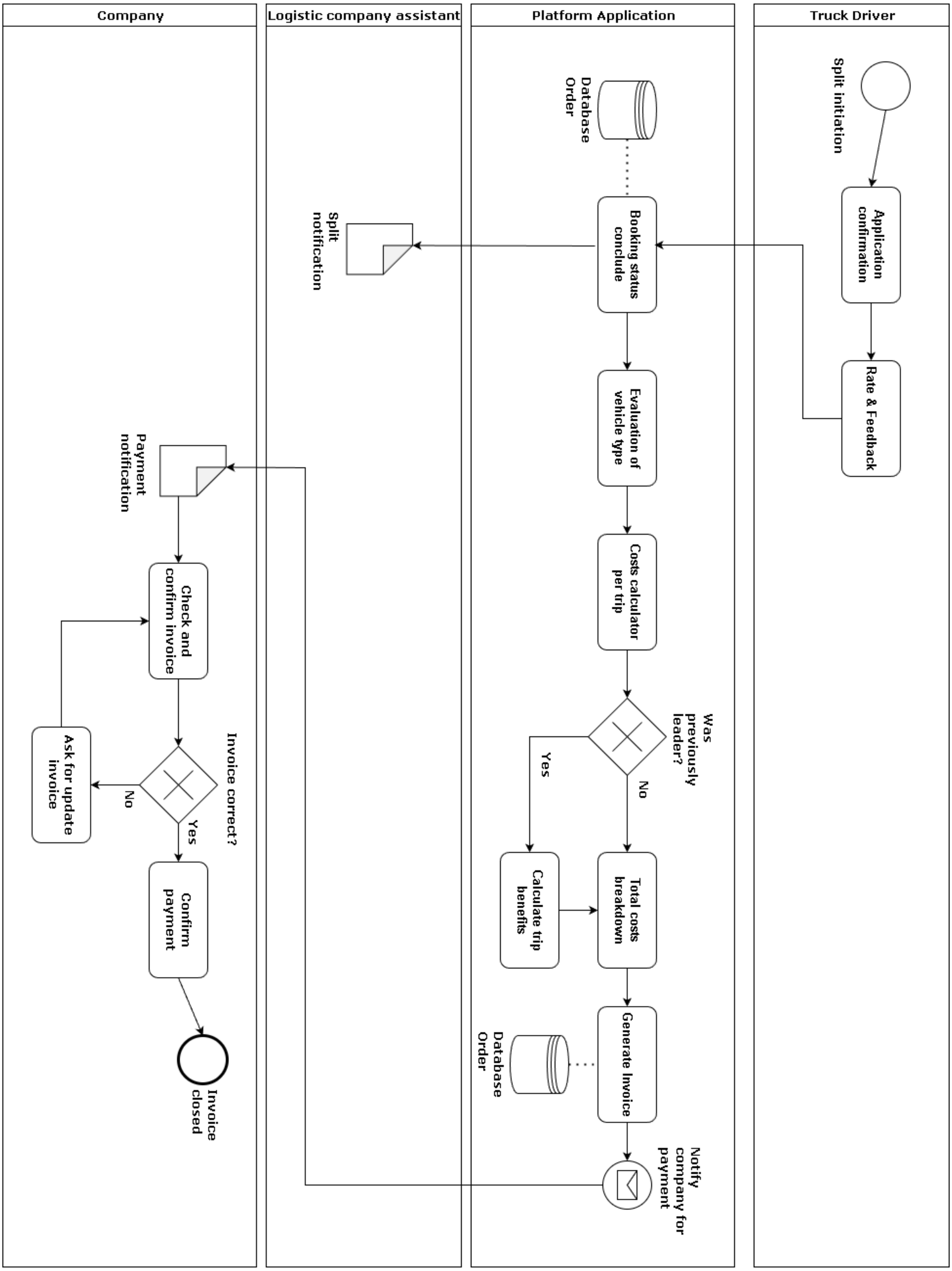
APPENDIX F: Second Use Case for Platoon Request (Different Companies)



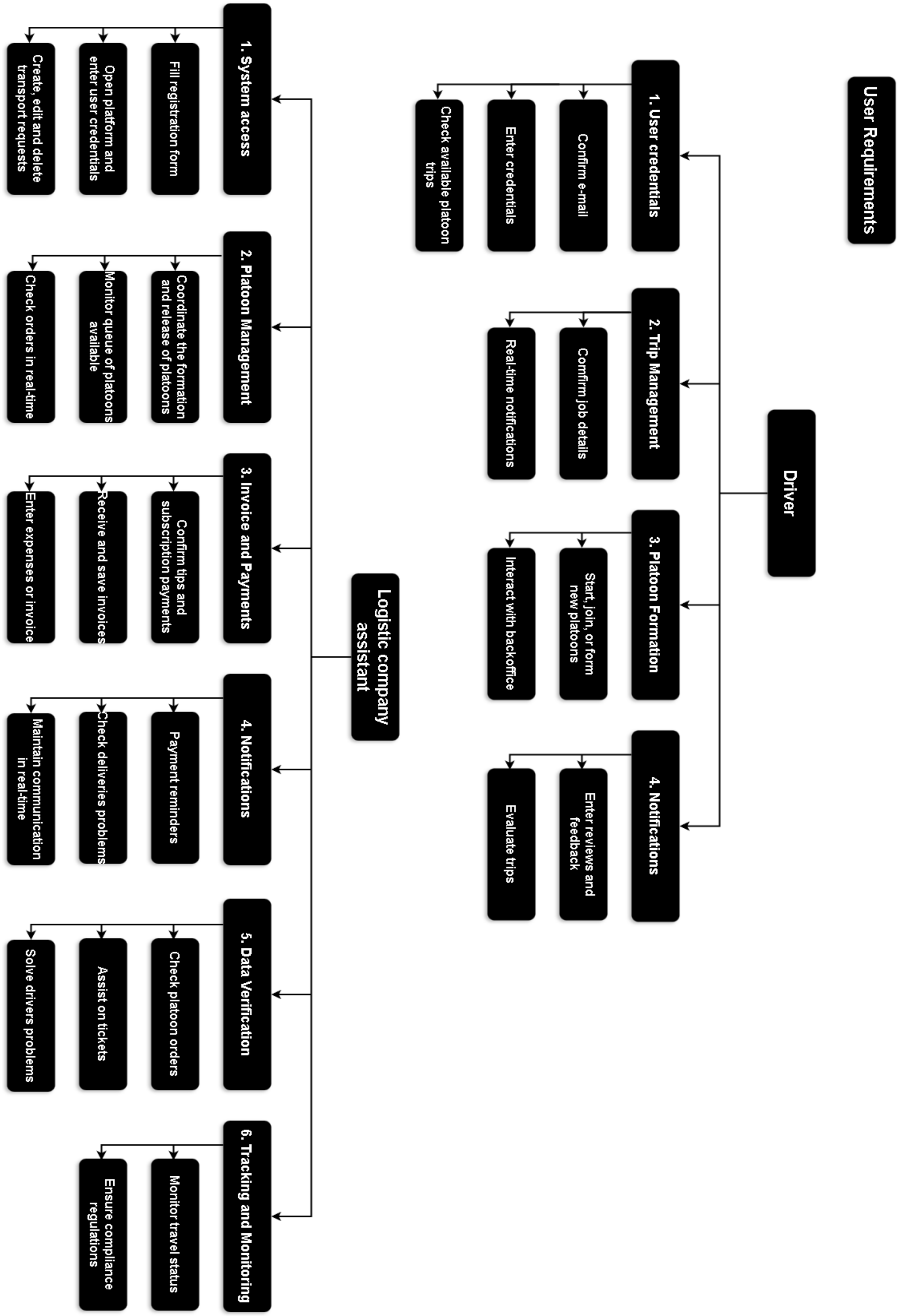
APPENDIX G: Third Use Case for Platoon Request (On-the-fly)



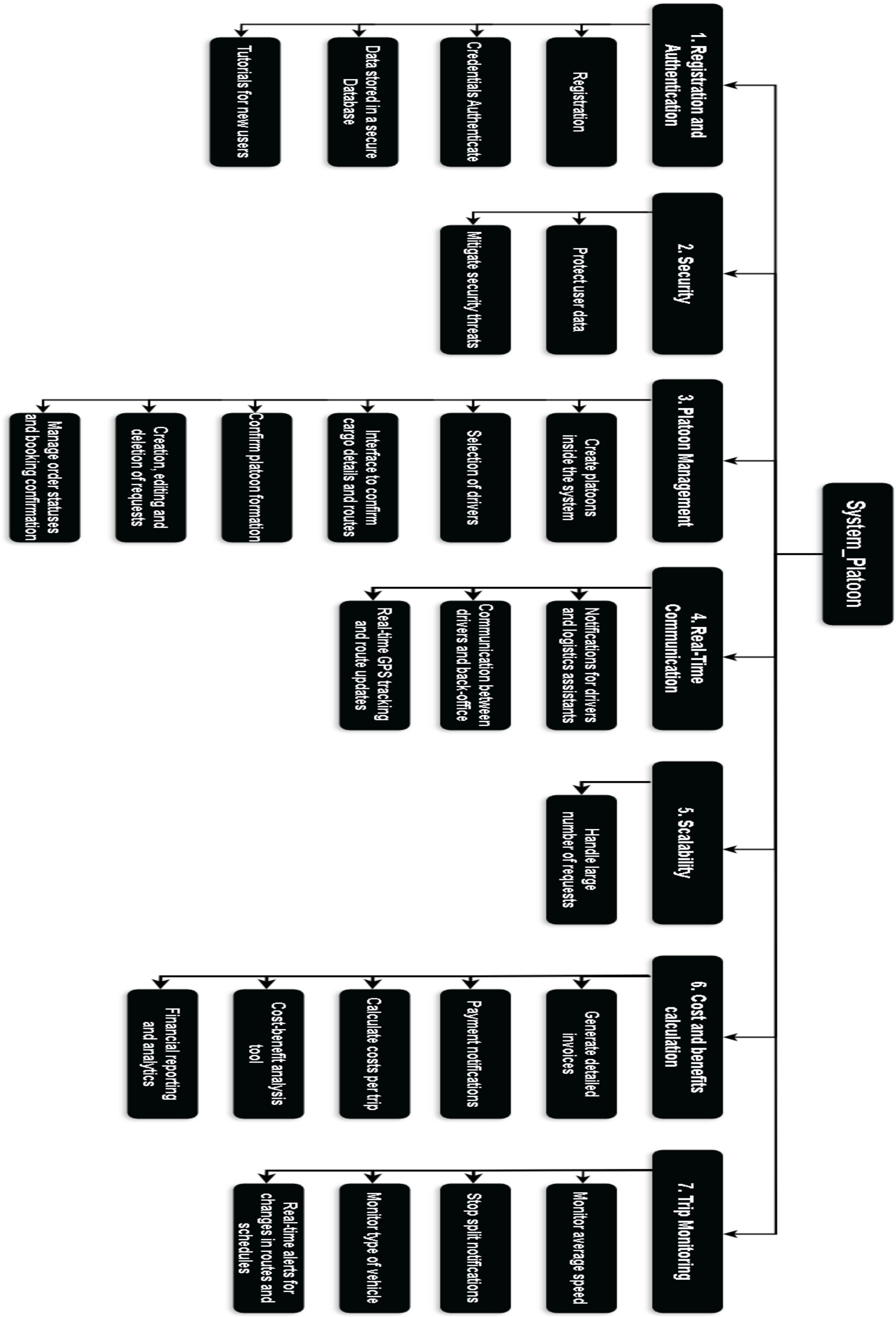
APPENDIX H: Feedback and Costs Splits



APPENDIX I: User Requirements



APPENDIX J: System Requirements



APPENDIX K: Microservices Design