Designing the future role of human operators in an autonomous bus system

A case study on Autonomous Airside Operations in Schiphol Airport

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Designing the future role of human operators in an autonomous bus system: a case study on Autonomous Airside Operations in Schiphol Airport

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Acknowledgements

Dear reader,

In front of you lies my master's thesis as a result of my graduation project to conclude the master's in Strategic Product Design at the faculty of Industrial Design Engineering at Delft University of Technology. With this graduation project, my education journey in Delft has come to an end. I can truly say that I enjoyed working on this project, as it allowed me to combine my background in Strategic Product Design with my passion for future mobility.

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My final word of thanks goes to my dear family, friends, and roommates, who supported me throughout the project. Thank you all for believing in me, for your optimism, and for giving me extra motivation during the final weeks.

I hope this research demonstrates how to integrate human-centered design principles in technology-driven innovation initiatives and serves as an inspiration for future researcher, innovators, and organizations.

To the readers, I hope you enjoy reading my thesis!

Femke van Dam
Delft, June 2024

Abbreviation

AAO - Autonomous Airside Operations

ATM - air transport movements

BIP - Bus Injection Point

CISS - Central Information System Schiphol

GPU - Ground Power Unit

HCD - Human-centered design

IH - Innovation Hub

LoA - Level of Automation

LoI - Level of Interaction

OPAS - Optimal Parking Assignment System

PRM - Passenger Reduced Mobility

RSG - Royal Schiphol Group

VOP - Vliegtuigopstelplaats (aircraft stand)

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1. Introduction

This chapter describes the project introduction. Section 1.1 gives an introduction of the project and Section 1.2 describes the methodology to approach the project.

Source: photo courtesy of RSG (2024)

1.1 The Project

This Section introduces the project's topic, design challenge, research goal, and involved stakeholders. Additionally, the methodology to approach the project is explained in Section 1.2.

1.1.1 Introduction to the project

This thesis is the result of the master's Graduation Project to obtain an MSc degree in Strategic Product Design. The project is done in close collaboration with the Delft University of Technology and Royal Schiphol Group. Royal Schiphol Group (RSG) created a vision for 2050 to create the world's most sustainable and high-quality airport. Therefore, Schiphol has initiated the Autonomous Airside Operations (AAO) team, which aims to make all vehicles and processes on the airside sustainable and autonomous. Automated vehicles, like autonomous buses, at the airside can enhance the efficiency and safety at the airport. Therefore, Schiphol is currently testing its first autonomous buses on a fixed route on the airside, where the cleaning personnel and tow truck drivers operate as the passengers, and a safety driver is present for manual takeover. After finishing the testing phase in May 2024, the bus system will be used in other use cases within airside operations.

In the future, there might be a possibility that the buses will be used to transport passengers between terminals and from the terminal to the airplane and vice versa. Even though, in time, Schiphol foresees the opportunity to fully automate nearly all airport processes, the human touch will remain an essential part of their good service proposition. Schiphol aims for a highly personalized and memorable experience.

"In a world where the necessity of human interaction has almost completely disappeared and touchless technology is the standard, we distinguish ourselves through our people, who 'go the extra mile' to make passengers feel welcome and valued."
- RSG (2020b)

The challenge for Schiphol is to determine the human operator role in an autonomous bus system within the context of an autonomous airside. Initiatives have already focused on new roles within autonomous buses: last year, the world's first autonomous bus service was launched, with a safety driver for manual takeovers and a 'bus captain' dedicated to facilitating a smoother bus journey for passengers (Cavforth, 2024).

1.1.2 Challenge

In their future vision, RSG made the assumption that the human touch is an essential part of maintaining a good service proposition in autonomous airside operations. However, this human touch or the interpretation of these human roles has not yet been determined. Therefore, the future role of human operators in an autonomous bus system in Autonomous Airside Operations (AAO) must be examined.

1.1.3 Goal

The goal of this research is to design the future human operator role in an autonomous bus system in the context of Autonomous Airside Operations by:

(1) understanding how the operators of the current bus system operate in the airside operations; and

(2) assessing an intervention for future human operator roles in an autonomous bus system in autonomous airside operations.

1.1.4 Research question

RQ: What are possible future roles of human operators in an autonomous bus system in Autonomous Airside Operations?

- **RQ1**: How to design a new human role in automated workplaces, considering human operators' perceptions of working with automated systems?
- **RQ2**: How do human operators interact with the current bus system in airside operations?
- **RQ3**: What are the different perspectives on the future human operator role and how does this differ from the current role?
- **RQ4**: What are scenarios where the autonomous bus system requires human intervention and what are the human operator roles in these scenarios?

1.1.5 Project stakeholders

This research includes multiple stakeholders. The project is a collaboration between the researcher, the Delft University of Technology, and Royal Schiphol Group. From an educational perspective, the Delft University of Technology is represented by the supervisory team. Royal Schiphol Group serves as the client. Indirect stakeholders in the research are participants from the shadowing sessions and the in-depth expert interviews and are sampled inside (i.e., bus drivers, bus coordinators, bus directors, service owners) and outside (e.g., researchers, technologists, people with experience in the implementation of autonomous transport systems, etc.) of the organization.

1.2 The methodology to approach the project

The research follows a **human-centered design (HCD)** approach (Zijlstra et al., 2014). Human-centered design is an iterative design approach that puts the needs, wants, and behaviors of users at the forefront of the design process (Norman, 2013). It seeks to create solutions that are intuitive, usable, and meaningful to the people who will interact with them (Zijlstra et al., 2014).

The decision to adopt a human-centered design approach for the design of the future human operator role in an autonomous bus system has been made. This choice is based on the recognition that the successful integration of technology relies not only on its technical capabilities but also on human operators, who will work in and interact with an autonomous bus system. By placing humans at the center of the design process, a value future human operator role can be created, that optimizes the performance of an autonomous bus system in Autonomous Airside Operations.

This research follows the steps that are taken in a human-centered design approach, which are presented in Figure 1:

1. Empathize: The first step involves understanding the human operator's perspectives, tasks, and interactions in the current operations. In this phase, the research is explored through literature research and context research, to define a relevant design challenge in a specific use case at the airside. Next, stakeholders (e.g., bus coordinators, bus drivers, bus service owners, etc.) are determined. Shadowing shifts are conducted with key roles and the insights are mapped out in a service blueprint to thoroughly understand the current passenger bus system operations. This includes the interaction between human operators and between a human operator and the bus. Based on in-depth expert interviews, their perceptions, and expectations towards the future role of human operators are determined in the context of airside operations.

2. Define: Based on the insights gathered, the design challenge is defined, where the research findings of the literature study, context study, and expert interviews are synthesized. After that, factors for the human operator role are distilled, which are used as a base for the ideation of future potential scenarios.

3. Ideate: In this phase, different future scenarios are designed where the human operator plays a crucial part in the autonomous bus system in Autonomous Airside Operations. A final concept is designed including these different scenarios and human operator roles.

4. Prototype: The final scenarios are used to create speculative design artifacts in the form of animation videos. First, storyboards for the different scenarios are designed. After that, animation videos are created.

Future work

In this research, the first four steps of the human-centered design approach are executed. In future research, the prototype could be tested and implemented, using the last two steps:

5. Test: The speculative design artifacts can be tested to gather feedback on contextual implications and to stimulate a rich discussion on future human operator roles.

6: Implement: Once the scenarios with human operators are evaluated, the concept can be refined, tested, and future human operator roles could potentially be implemented in a future autonomous bus system.

Human-centered design approach

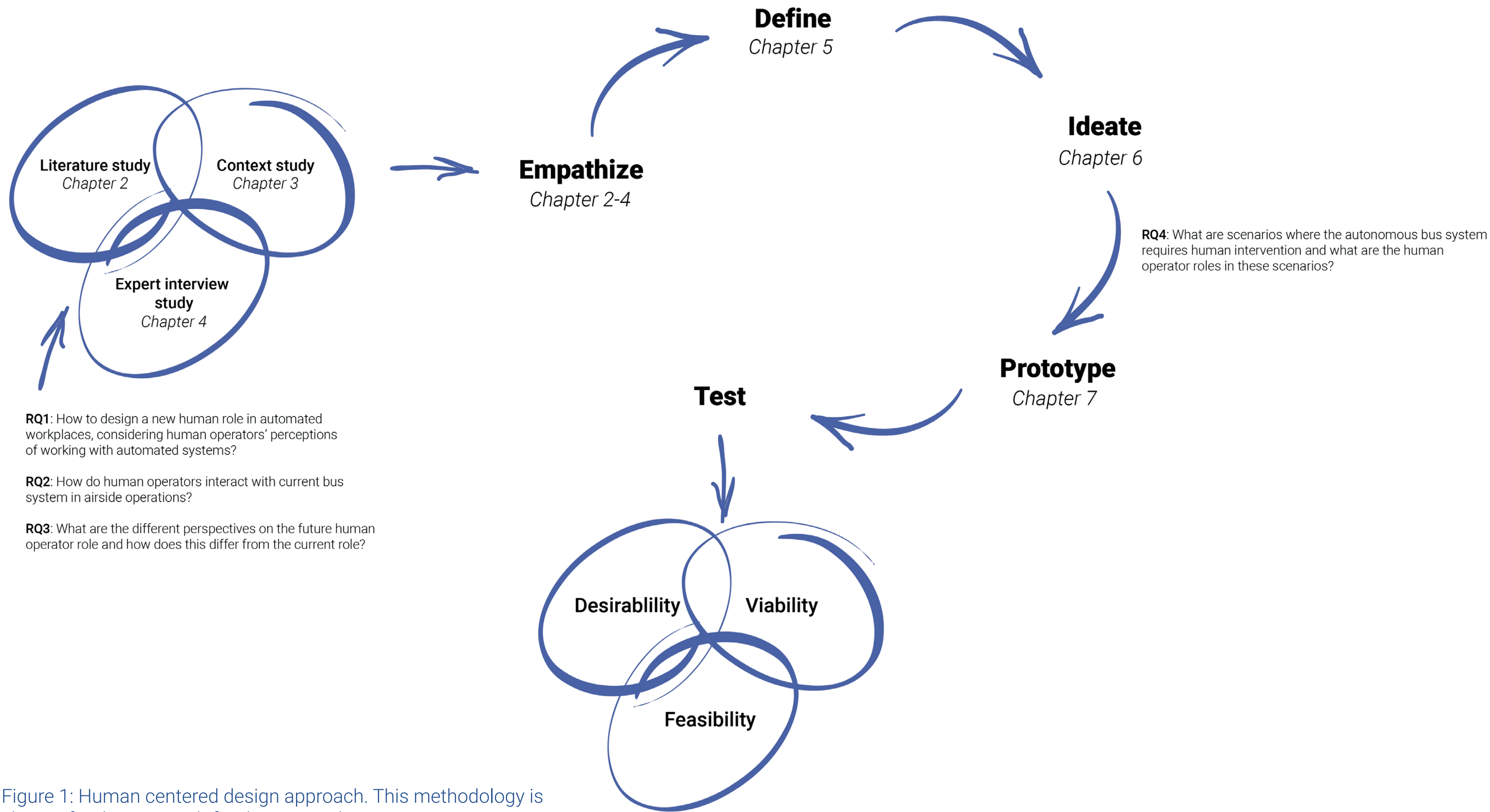


Figure 1: Human centered design approach. This methodology is chosen for the approach for this research.

2. Literature research

This chapter forms the theoretical foundation behind the project. It serves as preliminary research to understand how to design a new human operator role in automated workplaces, by considering prior work on how human operators perceive working in automated workplaces and by exploring possible frameworks for designing future roles (RQ1). Section 2.1 describes the methodology for the literature study. Section 2.2 explains how human operators remain essential in automated workplaces. Section 2.3 shows factors that influence how human operators perceive working in automated systems. Section 2.4 explains what frameworks can be used in designing a new human operator role. Section 2.5 presents the key insights gathered from the literature study.

Aim: To gain understanding of how to design new roles in automated workplaces, by understanding prior work on how operators perceive working in automated workplaces and by exploring possible frameworks for designing future roles.

RQ1: How to design a new human role in automated workplaces, considering human operators' perceptions of working with automated systems?

Source: photo courtesy of RSG (n.d)

2.1 Methodology

The aim of this literature study is to understand how to design a new human operator role in an automated workplace such as an automated bus system in airside operations, considering the perception of human operators working in automated workplaces. With this literature research, the focus lays on the first research question:

RQ1: How to design a new human role in automated workplaces, considering human operators' perceptions of working with automated systems?

The primary source of information in this Section is academic publications. The publications were found using the Association for Computing Machinery (ACM) database, Springer, Science Direct, and Google Scholar. The following keywords were used during the search: "automated workplace", "human operator", "human factors", "human-computer interaction", "future of work", "work design", "job design", and "human-centered automation". Sequential sampling is initially used, where articles are iteratively sampled in multiple rounds till additional articles no longer contribute to new insights. After that, snowball sampling was used based on insightful articles that were relevant to the research.

2.2 Human operators in automated workplaces

In the past decades, automation exponentially integrated into our workplaces, from robotics in the healthcare sector (Yang et al., 2019; Yang et al., 2016), to autonomous vehicles in public transportation (Chu et al., 2023; Karvonen et al., 2011; van Fossen et al., 2023; S. Yang et al., 2018; Bhoopalam et al., 2021; Orii et al., 2021). In this research, automation is defined as the process wherein technologies (e.g., robots, computers, machines, algorithms, etc.) independently execute functions that previously relied on human labor (Parasuraman & Riley, 1997). From a human perspective, automation refers to a device or a system that accomplishes (partially or fully) a function that was previously or conceivably could be, carried out (partially or fully) by a human operator (Roto et al., 2019).

In the context of this research, the implementation of autonomous innovations, such as autonomous buses, could bring many benefits to the airport, increasing efficiency and precision, becoming less dependent on human workers, and addressing the constraints of human operators in uncomfortable and repetitive physical tasks (Gomez-Beldarrain et al., 2024). However, innovations regarding autonomous systems are mainly technology-driven, and human factors are subordinated, which results in poor autonomous system design. During implementation, consequences for human operators (e.g., worker dissatisfaction, high cognitive demand, lack of trust, automation-related job insecurity, etc.) become visible and the reluctance to accept autonomous innovations by human operators increases (Parasuraman & Riley, 1997; Dietvorst and Bharti, 2020).

Even though the introduction of automation in workplace processes has raised concerns about the potential loss of all human operator jobs, studies claim that the human operator will still be essential in automated workplaces (Chu et al., 2023; Roto et al., 2019; Bradshaw et al., 2013), where automated tasks coexist alongside other tasks that are not automated (Parker & Grote, 2022). Roto et al., 2019 complement this by stating that most automated systems can operate to an extent where humans can still intervene and change the decisions of automated systems. However, the tasks and therefore the role of the human operator will change (Bradshaw et al., 2013).

So, studies emphasize the future importance of human operators in automated workplaces. However, determining how the role of human operators evolves in such environments remains a challenge. Addressing this human element in automated systems is crucial for the successful implementation of automation.

2.3 Factors that influence how human operators perceive working with automated systems

How human operators perceive automation, what their attitude is toward their changing role and the impact of automation on them have been studied in different contexts, and the outcome varies (Parker & Grote, 2022; Selenko et al., 2022; Smids et al., 2020). Human operators' beliefs that technology can conduct their work automatically relate to pessimistic and optimistic assessments regarding how automation will impact job prospects. In some cases, automation is harmful, leading to poorer-quality jobs (Gödöllei & Beck, 2023). In other cases, employees benefit from automated working conditions, enhancing safety, productivity, and more meaningful occupations (Gödöllei & Beck, 2023).

As mentioned before, human-centered design principles are essential for the successful implementation of autonomous systems. So, understanding how human operators perceive automation can serve as valuable information for managing workforce transitions to design effective human-centered automated systems. Studies show that human operators' trust in autonomous systems, their understanding of autonomous systems, their accountability for the decision-making and work outcome, and the level of automation are factors that affect how human operators perceive automation, which is further explained in Subsection 2.3.1 - 2.3.4.

2.3.1 Trustworthiness

In regards to trust in automated workplaces and decision-making, automated decisions seem to primarily result in less trust compared to human decisions (Höddinghaus et al., 2021; Lee, 2018). Research shows that the more operators trust automated systems, the more they tend to use them. On the other hand, when operators trust their own abilities more than those of the system, they are more inclined to choose manual control instead (Wang et al., 2016). A reason for this is that automated systems can sometimes lack transparency, leading to what is known as the 'black box' phenomenon, which causes the operator to resist trusting the system (Panchal, 2023). Initially, human operators seem unsure about the performance of automated systems (Langer & Landers, 2021). Operators will place greater trust in automated systems when they have a more accurate understanding of their decision-making process (Wang et al., 2016). More transparency in automated systems will make it understandable and meaningful for human operators, resulting in more trust in automation (Panchal, 2023).

2.3.2 Understanding automated systems

The understanding of automated systems affects the quality of work among human operators. Schuster et al. (2021) show anxiety among human operators over the uncertainty of not knowing how their jobs will be affected. When designing a future operator role in automated systems, the challenge arises that human operators are usually low-income workers who depend on their operating skills but have little knowledge about automation (Chu et al., 2023). Based on a study with safety drivers, Chu et al. (2023) show that safety drivers are restricted to self-development in working with new automated processes since they are the first operators working in this automated system. By calibrating their perceptions while working with AVs, the safety drivers create more understanding of the automated system over time.

2.3.3 Accountability in decision-making and work outcome

In an autonomous workplace, where human operators work alongside automated systems, studies show a concern that there will be an accountability gap, which occurs when it is not clear who is obliged for errors and human operators then rely on automated systems (Langer & Landers, 2021; Raji et al., 2020). In unexpected situations, when errors occur, Karvonen et al. (2011) identify challenges faced by human operators including the demands for dynamic, complex, and uncertain control, and the risk of decision-making. Additionally, when a shared decision is made between a human operator and an autonomous system, human operators and other stakeholders do not know who to blame for possible negative outcomes of the decision (Langer & Landers, 2021).

2.3.4 Level of Automation

“Autonomous” and “automated”, are terms that are used interchangeably in the context of self-driving buses. However, there is a difference between “automated” and “autonomous”. According to Wood et al., 2012, “automated” implies control or operation by a machine, while “autonomous” involves acting alone or independently. For this research, we focus on autonomous buses, where automation is defined as the process wherein technologies (such as robots, computers, machines, algorithms, etc.) independently execute functions that previously relied on human labor (Parasuraman & Riley, 1997). From a human perspective, automation refers to a device or a system that accomplishes (partially or fully) a function that was previously or conceivably could be, carried out (partially or fully) by a human operator (Roto et al., 2019).

For autonomous vehicles, six different levels of automation are determined by The Society of Automotive Engineers (SAE) (Figure 2). These Levels of Automation have become the industry standard. The levels move from having no driving automation (level 0) towards full automation (level 5). Level 5 of automation refers to a fully autonomous system that expects the vehicle’s performance to equal that of a human driver in every scenario (SAE, 2021). Currently, in the Netherlands, it is permitted to operate a Level 3 autonomous bus in mixed traffic environments, meaning that the buses require an operator on board during operations. During this LoA, the operator’s tasks include monitoring the system and ensuring safety by manually taking over when necessary (Biletska and Beckmann, 2023).

With levels 4 and 5 of automation, it is not necessary anymore to have a human operator on board of the bus. Instead, the bus can be monitored and controlled remotely by a human operator, which results in a task shift for the human operator role (e.g., classification and prioritization of various requests, remote control, infrastructure monitoring, passenger communication, etc.) (Biletska and Beckmann, 2023). Karvonen et al. (2021) highlight the potential monotonous work routine that comes with evolved automated systems and shed light on the importance of considering the human factor in the design.

As a result of the integration of automation, tasks performed by human operators will likely be replaced by automated systems, meaning that humans consequentially have limited power and voice in the workplace. This results in less acceptance in automated processes by human operators (Cheon et al., 2021). Human operators feel threatened by the increasing level of automation, causing anxiety due to widespread uncertainty and the loss of control (van Fossen et al., 2021). Additionally, studies show that there are psychological effects linked to how much control human operators have and whether they get to make the final decisions (Newman et al., 2020). So, the level of automation affects human operators’ perceptions of automated systems and results in a reluctance to adopt automation (Langer & Landers, 2021).

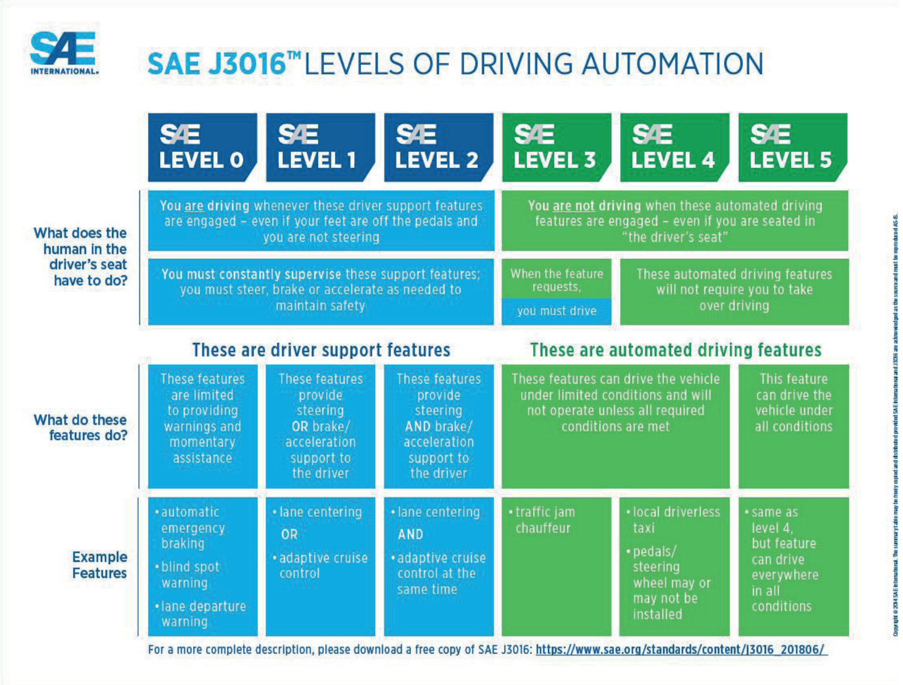


Figure 2: Levels of driving automation (SAE, 2021)

2.4 Work design in automated workplaces

As mentioned before, research shows that the implementation of automation in the workplace can affect key aspects of work, resulting in a limited level of autonomy, control, and decision-making (Cheon et al., 2021; Yang et al., 2016; Yang et al., 2019). Therefore, future work arrangements, in a context where human operators have limited power and control in the workplace, need to be made (Cheon et al., 2021). With work design, which refers to a focus on the "content and organization of one's work tasks, activities, relationships, and responsibilities" (Parker et al., 2017, p.662), we can design toward a human-centered future of work in an automated workplace.

Literature shows the importance of why work design matters more than ever when automation is integrated into daily operations (Parker & Grote, 2022). Functionally, automation can (a) complement and support existing human work tasks, (b) replace existing human work, and/or (c) create new human tasks and subsequently new work roles (Acemoglu & Restrepo, 2019; Brynjolfsson & Mitchell, 2017). To deal with automation effects and to guide technology toward the desired work circumstances, jobs need to be redesigned. Additionally, the implementation of automation in daily operations poses the challenge of defining the new human roles that will be required to support it (Gomez-Beldarrain et al., 2024).

To fully understand how work design and automation relate to each other, Parker & Grote (2022) address the need for detailed study for work in context, which is relevant for understanding the complex interactions between human operators, technology, higher-level forces (e.g., management choices), and other factors. Yang et al. (2019) complement this by highlighting the necessity to design automated processes as an integrated experience, situated within its social and physical context such as workplace culture and social structures.

2.4.1 Job characteristics in work design

To design future work that is aimed at creating job satisfaction, Hack man & Oldham (1976) created a framework, named the Job Characteristic Model (Figure 3). This framework became the standard approach to work design and still provides the foundation for designing future roles (Oldham & Fried, 2016).

The model focuses on five core job characteristics that contribute to internal work motivation, growth satisfaction, job satisfaction, and high work effectiveness. The job characteristics are:

1. **Skill variety** (i.e., the degree to which the job requires a variety of different activities involving the use of different skills)
2. **Task identity** (i.e., the degree to which the job requires doing a whole and identifiable piece of work),
3. **Task significance** (i.e., the degree to which the job has an impact on the lives of others)
4. **Autonomy** (i.e., the degree to which the job provides substantial freedom to the employee)
5. **Job-based feedback** (i.e., the degree to which carrying out the work provides the employee with performance information).

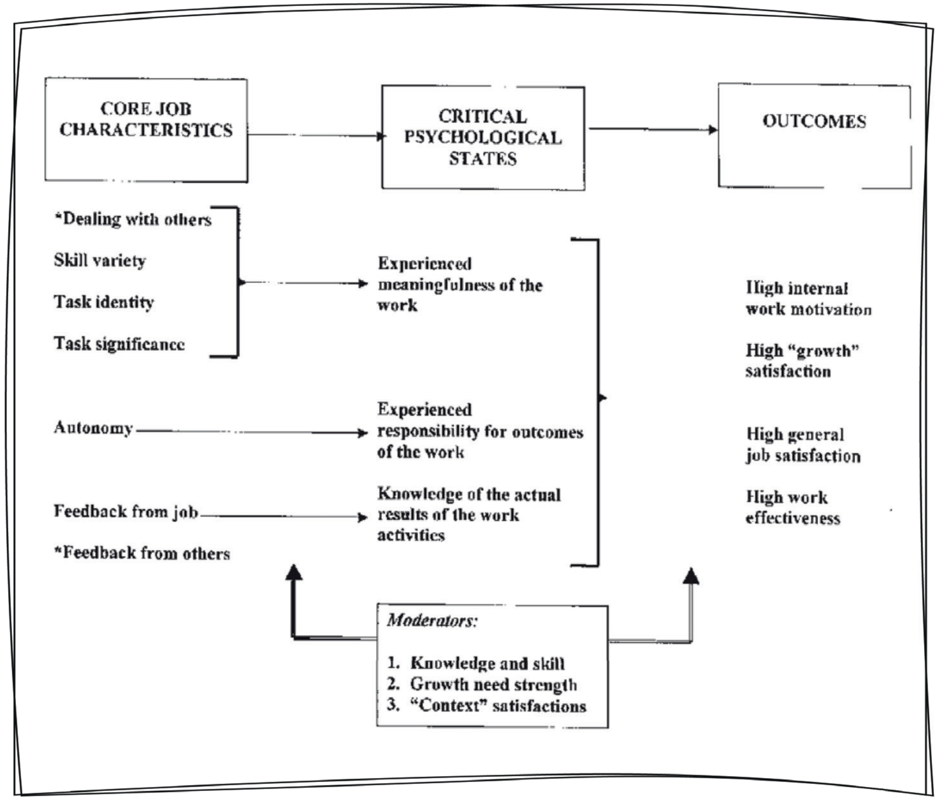


Figure 3: Job Characteristics Model (Hackman & Oldham, 1976)

2.4.2 Impact of automation on the Job Characteristics Model

When automation integrates into workplaces, this will have a significant effect on the job characteristics of human operators. First, the skill variety and task identity will be affected. Low cognitive and repetitive tasks can be easily taken over by automated systems, which results in more freedom for human operators to do more complex tasks (Waschull et al., 2020). However, the variety decreases with a higher level of automation. Human operators will have a more supervisory role for automated systems and will react when manual take-over is required (Reil & Leyer, 2021).

The level of Autonomy can affect the future role positively or negatively, depending on the distribution in the decision-making process (Reil & Leyer, 2021). Human operators can feel empowered as they gain the feeling of still being in control. However, when automated systems overtake decision-making, the perceived control decreases (Leyer et al., 2018) and therefore job satisfaction suffers.

In regard to job-related feedback, automated systems could provide nearly instant feedback to human operators on their performances. Additionally, more interactions between human operators and autonomous systems occur, resulting in a cooperative collaboration with small feedback loops (Morgeson & Humphrey, 2008). This will have a possitive impact on the job characteristic 'feedback from job', resulting in increased job satisfaction.h

In conclusion, automated systems often alter or diminish these job characteristics. Therefore, traditional models like the Job Characteristics Model from Hackman & Oldham (1976) become less applicable as automation shifts the nature of work, meaning that it is essential to adopt other methodologies in designing future roles in automated systems.

2.4.3 The use of speculative design in designing future roles

Prior work focussed on exploring alternative frameworks for the design of future roles. Fox (2023) used speculative design to gather nuanced, context-specific feedback on automated systems. This approach aligns closely with human-centered design principles and ensures that the design of future human roles remains adaptable and human-focused, despite the evolving landscape of automated workplaces. Speculative design is a research approach that focuses on envisioning and exploring possible futures. It involves creating artifacts, scenarios, and narratives to represent alternative futures. These artifacts are not intended to be practical solutions but are instead used as tools for reflection, debate, and inquiry (Dunne & Raby, 2013).

The use of speculative design in qualitative research is familiar in prior work and is widely used to explore future technologies and the future of work: Lin and Long (2023) applied speculative design to explore plausible scenarios for generative AI and human coexistence. Additionally, Yams and Muñoz (2021) used speculative design to explore the future of work. Also, Grafström et al., (2022) show that speculative design is a suitable method to investigate potential interactions between humans and an automated system, in their case an assistant robot cleaner.

Studies show that speculative design is a suitable method to bridge differences between participants coming from a variety of backgrounds (Auger, 2013), to find creative ways for people with non-technical backgrounds to get engaged with abstract topics (Yams & Muñoz, 2021). Additionally, speculative design is suitable to use as a probe tool to explore possible future scenarios (Al-frink et al., 2023).

Based on the prior work of Fox (2023), Lin and Long (2023), Yams and Muñoz (2021), and Grafström et al. (2022), the following steps can be identified to apply speculative design in designing future roles:

1. Identifying the context and stakeholders.
2. Creating speculative artifacts.
3. Engaging stakeholders with the speculative artifacts.
4. Gathering context-specific feedback.
5. Analyzing the feedback.
6. Iterating on the design.
7. Reflecting on the process.

2.4 Key insights

The successful adoption of autonomous systems is challenging for organizations because these innovations are mainly technology-driven, often neglecting human factors, which results in poor autonomous system design (Parasuraman & Riley, 1997; Dietvorst & Bharti, 2020). Despite the increasing automation, human operators remain essential in automated workplaces. However, their roles are evolving (Bradshaw et al., 2013), meaning that it requires a human-centered approach in designing automated systems to ensure they are successfully adopted by human operators.

Furthermore, the interpretation of human operator roles in autonomous workplaces is highly context-dependent and requires further exploration for successful implementation (Palanque et al., 2021). Understanding these context-specific dynamics is crucial for the successful implementation and adoption of autonomous systems that are both efficient and supportive of human operators (Xing et al., 2021).

Prior research has primarily focused on evaluating the impact on human operators after the implementation of automated systems. These studies have identified several factors that negatively influence how operators perceive working in automated workplaces (Figure 4), including:

- A lack of trust in autonomous systems due to their opaque decision-making processes (Höddinghaus et al., 2021; Lee, 2018; Panchal, 2023).
- Misunderstandings or insufficient knowledge about how these systems function (Chu et al., 2023).
- Accountability gaps between human operators and automated systems, leading to confusion over responsibility for errors (Langer & Landers, 2021; Raji et al., 2020).
- Reduced levels of decision-making authority and control for human operators, which can lead to decreased job satisfaction (Langer & Landers, 2021).

However, these studies have not addressed the proactive redesign of work roles to accommodate automation. There is a need to redesign human operator roles in automated workplaces. Hackman & Oldham (1976) created a framework that shows job characteristics to consider when designing future roles. The model focuses on key factors (Figure 4): skill variety, task identity, task significance, autonomy, and feedback. These elements are essential to maintaining job quality and satisfaction.

Nevertheless, automated systems often alter or diminish these job characteristics. Therefore, traditional models like the Job Characteristics Model from Hackman & Oldham (1976) become less applicable as automation shifts the nature of work, meaning that it is essential to adopt other methodologies in designing future roles in automated systems.

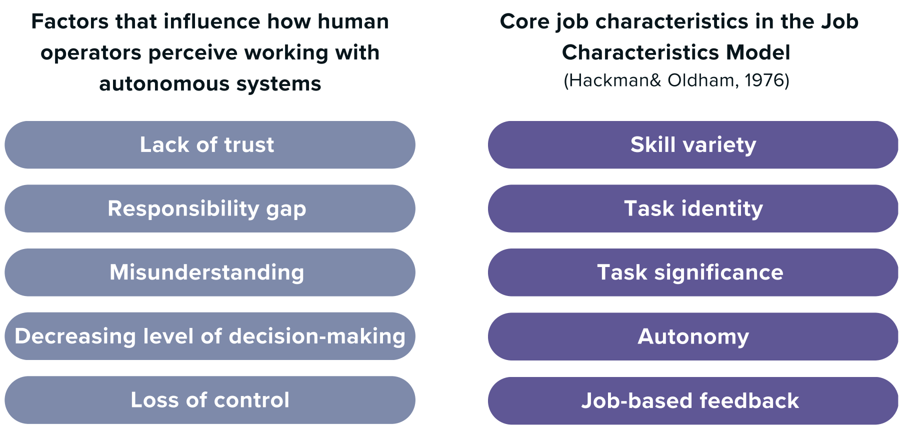


Figure 4: Overview of the main insights from the literature study

Prior work (Fox, 2023; Lin and Long, 2023; Yams and Muñoz, 2021; Grafström, 2022) focused on exploring the use of speculative design for designing future roles. This approach aligns closely with human-centered design principles and ensures that the human roles successfully spport the automated system. To design human-centered future roles, prior work (Fox, 2023) on speculative design is combined with the Job Characteristics model (Hackman and Oldman, 1976), and a human-centered design approach (Zijlstra et al., 2014), resulting in the following framework, presented in Figure 5.

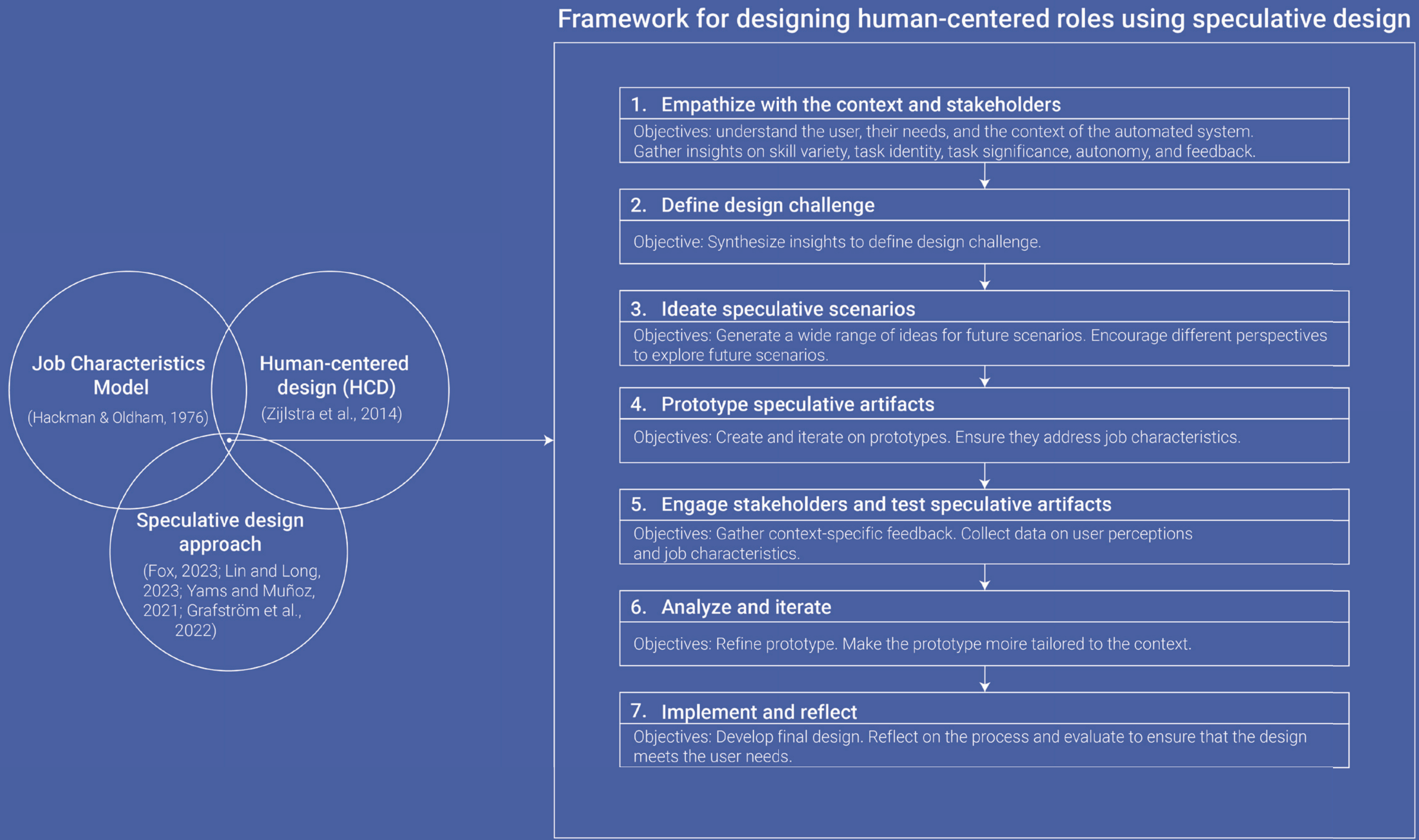


Figure 5: Combined framework for designing future human-centered roles using speculative design. The framework is designed by combining the job characteristics based on Job Characteristics Model (Hackman & Oldham, 1976), with human-centered design principles (Zijlstra et al., 2014), and speculative design research.

In conclusion, while studies show an understanding of the post-implementation impacts of automation on human operators, there is a clear gap in the proactive, human-centered design of work roles. Future research should focus on developing a human-centered framework for future human operator roles (Figure 5). Following such a framework, future roles require to be further determined in a specific use case, such as an autonomous bus system in airside operations, for the successful implementation of automated systems.

3. Understanding the current context: Schiphol Airport

Before delving into the role of the human operator in an autonomous bus system, it is crucial to understand the current operational context in which an autonomous bus system might operate. Therefore, this Section serves as preliminary research to better understand the different roles of current human operators and interactions between each other and the bus (RQ2). Section 3.1 shows the current airport context and its vision towards an autonomous airside. In Section 3.2, a potential future use case for autonomous buses is determined, namely the boarding and deboarding procedure at bus gates. While the work procedures of the different roles and other internal documents of Schiphol are a solid base for understanding the context, the small interactions of the human operators with the bus system and the supporting processes are not evident. Therefore, a qualitative study is conducted in Section 3.3 in the form of shadow shifts, to uncover what the different roles and interactions of the human operators include in the current bus system. Section 3.4 presents the key insights based on the observations during the shadow shifts.

Aim: To gain understanding of the current bus system context at Schiphol Airport by identifying key roles, work tasks, and interactions between human operators and the bus.

RQ2: How do human operators interact with the current bus system in airside operations?

Source: photo courtesy of RSG (n.d)

3.1 The airport environment

3.1.1 The airport's vision towards an autonomous airside

This research project is undertaken in the context of Amsterdam Airport Schiphol, an international airport in The Netherlands that is part of the Royal Schiphol Group (RSG). RSG created a vision for 2050 to create the world's most sustainable and high-quality airport (RSG, 2020b). The vision of 2050 consists of three pillars: the Quality of Life, the Quality of Service, and the Quality of Network. Based on these pillars, Schiphol has initiated the Autonomous Airside Operations (AAO) initiative, which aims to make all vehicles and processes on the airside sustainable and autonomous, including an autonomous bus system. The Autonomous Airside Operations team is part of the Schiphol Innovation Hub, which plays a role in testing and iterating radical innovation within the airport context (RSG, 2020b).

Schiphol Airport welcomed 61.9 million passengers in 2023, which is a 17,9% increase compared with 2022. Additionally, the airport recorded a total of 441,969 air transport movements (ATMs), an increase of 11.1% compared with 2022 (RSG, 2023.). To adapt to increased capacity, Schiphol has the need to develop efficient, sustainable, and autonomous systems.

A strategic roadmap, consisting of all the milestones in the transition towards an autonomous airside in 2050 along with the indicated timeline, is designed by RSG (Figure 6). Each touchpoint in the roadmap is an operational process that can be automated. For the scope of this research, we will focus on the human operators, who fall into the "Human factors" in the "Transformation" enablers section. Additionally, the autonomous bus initiative falls into the "PAX transport".

3.1.2 Current autonomous bus initiative on Schiphol's airside

As mentioned before, RSG initiated the Autonomous Airside Operations project (RSG, 2020). The airside refers to the section of the airport designed to support aircraft and their resources, along with the movement of travelers and baggage. Airside operations cover a range of procedures, including aircraft ground handling, air traffic control, aircraft marshaling, aircraft pushback and towing, aircraft de-icing, apron management, etc.

The airside is a complex ecosystem, where multiple stakeholders perform time-critical functions in a highly regulated environment. Therefore, RSG foresees an interesting opportunity to automate complex processes at the airside, to adapt quickly, be more efficient, and become more sustainable.

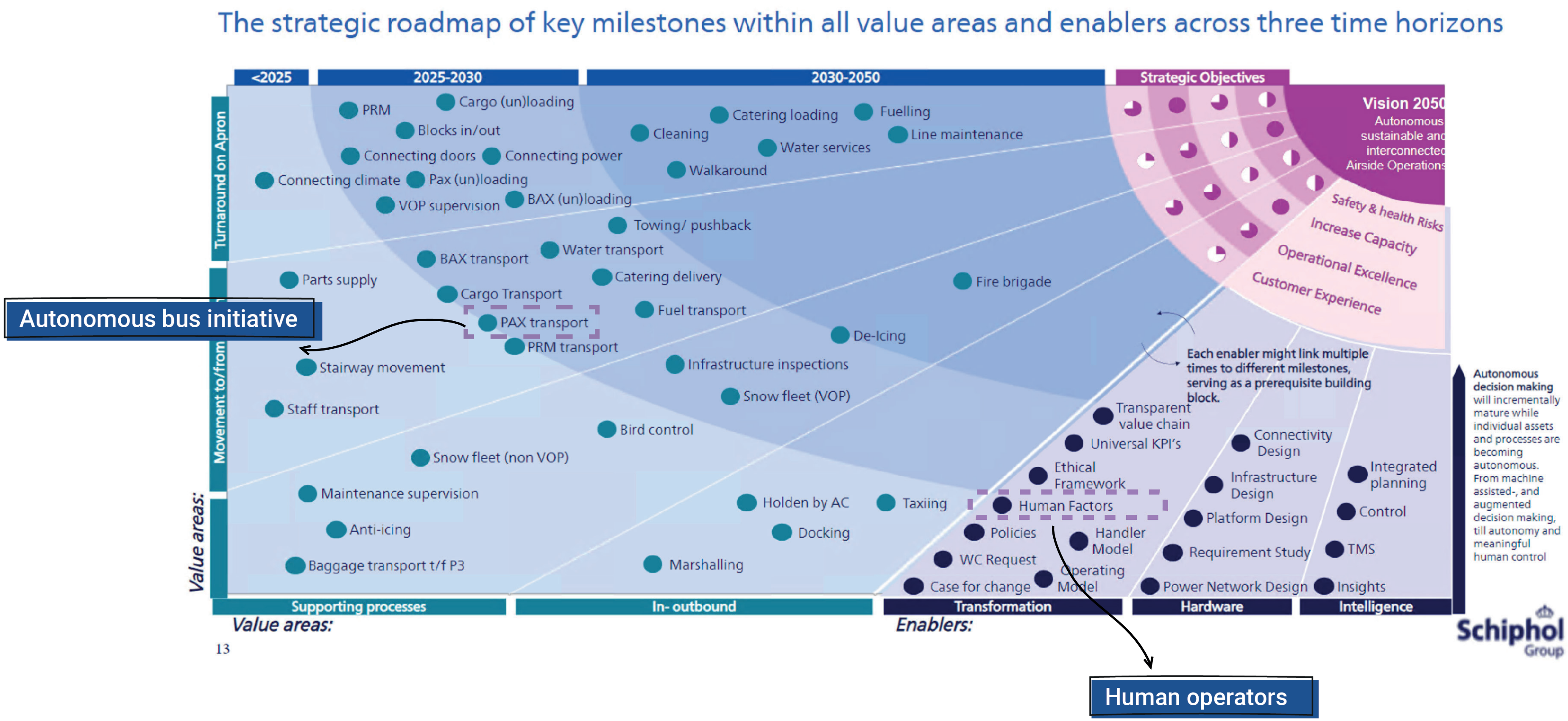


Figure 6: Schiphol's 2050 vision roadmap. "Human factors" presented in the "Transformation" pillar. The autonomous buses fall into "PAX transport", presented in the "Movement to/from Apron" Section.

One of the current projects of the AAO initiative is the autonomous bus project. The autonomous buses are currently tested for "Staff transport", which is one of the operational processes stated in the strategic roadmap (Figure 6). This testing phase started in October 2023 and will end in May 2024. The initial goal of the testing phase was to adapt the autonomous bus technology to the complex environment of Schiphol Airport. The testing initiative takes place on a fixed route at the airside at Door 60 around the H-platform, with the bus transporting cleaning staff and tow truck drivers. The bus takes the personnel from the security to their workplace on the airside and vice versa (Figure 7). The bus model that Schiphol uses during the test phase is called Lift, an autonomous bus from a supplier from New Zealand called Ohmio.

On the airside, the autonomous bus encounters various vehicles (e.g., tow trucks, ground power units (GPUs), etc.). Therefore, the challenge is to integrate the autonomous bus system seamlessly into airside operations. The testing initiative at Door 60 functions as a proof of concept and tests the technology acceptance within the organization. During the testing phase at Door 60, the technology of the autonomous buses is adapted to Schiphol's complex environment, which includes a range of different vehicles, various traffic rules, and specific infrastructure conditions.

The bus is operating with a safety driver onboard during the current testing phase. This is mandatory since the buses are operating at Level 3 of Automation (LoA), according to the SAE framework (SAE, 2021). The safety driver is responsible for monitoring the vehicle and for manually interrupting the vehicle in case an error occurs.

While the focus is currently on the Door 60 use case, Schiphol Airport plans to continue testing and aims to explore other potential use cases that can add value to the airport ecosystem (i.e., crew transport from the gate to the city hopper airplanes, crew transport around the piers to the apron and back, transport operational tools around the airside, passenger transport between terminals, or passenger transport between terminal and aircraft).

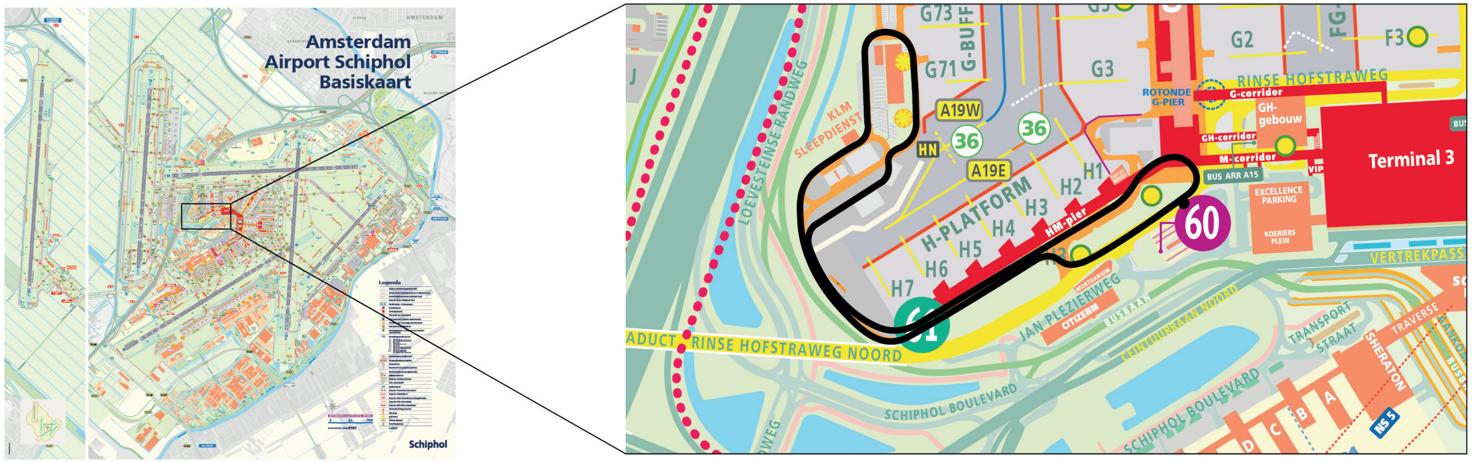


Figure 7: Door 60 route where the current autonomous bus initiative is being tested

3.1.3 Future use cases for an autonomous bus system

In the future, RSG envisions the potential of transporting passengers between terminals and from the gate to the aircraft and back (Schiphol, 2020b). To further develop potential passenger transportation, it is necessary to identify current scenarios where passengers are transported by buses at the airport, which have the potential to become autonomous. These different potential use cases can be identified based on the current usage of buses at the landside and the airside (Figure 8). First, current buses on the landside are used at the arrival and department at Schiphol's central hub, called the Plaza. The bus systems that operate here are city and regional transport to surrounding cities (e.g., Amsterdam, Leiden, Lisse, Haarlem, etc.). Additionally, shuttle buses operate on the landside from the Plaza to the parking zone P3/P4 and back (RSG, n.d.). Lastly, shuttle bus services are utilized from and to the logistic hub and construction sites. Different bus companies (i.e., GVB, R-Net, and Arriva) are responsible for these operations (Arriva Touring, 2020). On the airside, buses are being deployed for the transport of passengers on the apron, to move travelers from the terminal to the airplane and vice versa (RSG, n.d.). Schiphol foresees the possibility to also use autonomous buses for the transport of travelers to other terminals. Besides passengers, current buses are also used for the movement of personnel on the airside.

For this study, we focus on a future use case on passenger movement in airside operations. While autonomous buses may also be relevant on the landside of an airport, the airside offers a more controlled and suitable environment for the implementation of autonomous buses due to its greater emphasis on efficiency and safety, and the opportunity for controlled implementation. Additionally, RSG already started testing initiatives on controlled routes at the airside (i.e. Door 60), where personnel is transported. However, passenger transport has not yet been explored.

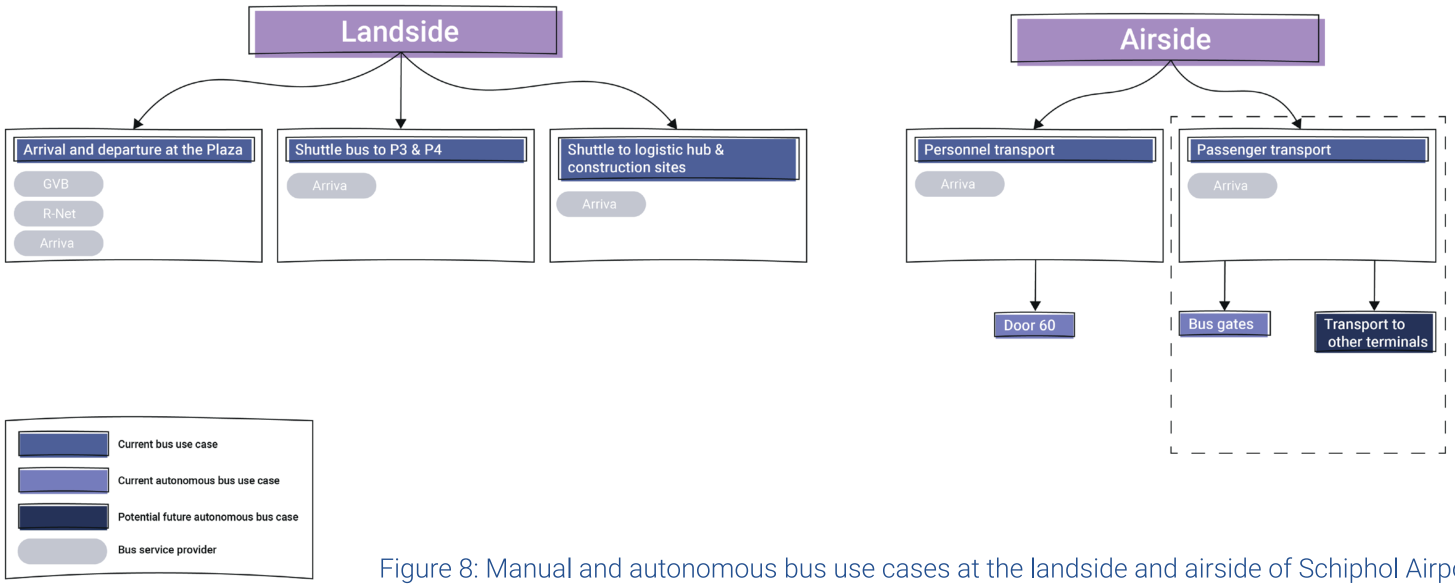


Figure 8: Manual and autonomous bus use cases at the landside and airside of Schiphol Airport

3.2 Boarding and deboarding procedure at bus gates at Schiphol Airport

A use case where a bus system is essential to transport passengers on airside at Schiphol Airport is during the boarding and deboarding at remote gates, also known as bus gates. Human operators follow a fixed procedure that is used in this scenario, which is called the bus@gate procedure during boarding and deboarding and will be further explained in this Section. The role descriptions and tasks of different human operators in the current bus procedure are gathered from internal documents from RSG (e.g., work instructions, procedure factsheets, safety protocols, etc.) and form the basis of the context study on how operators interact with the current bus system in airside operations (RQ2).

3.2.1 Bus gates

In recent years, Schiphol Airport has been facing increasing challenges in managing the congestion flow of passengers. As one of Europe's busiest airports, Schiphol handles millions of passengers annually. To accommodate the growing number of passengers, it is necessary to optimize streamlined procedures to minimize congestion. One such innovative approach implemented at Schiphol is the bus@gate procedure, which aims to optimize the boarding and deboarding process by utilizing shuttle buses to transport passengers directly from the aircraft to the terminal gates and vice versa. By implementing this procedure, Schiphol can use remote gates to increase capability. Remote gates are gates that are not directly located next to the terminal. In the current operations, almost 20-25% of the flights arrive at or depart from bus gates (based on internal conversations with employees from RSG).

3.2.2 Bus@gate procedure

To increase capability during peak moments and increase efficiency, Amsterdam Airport Schiphol has the opportunity to allocate airplanes at one of the 98 remote aircraft stands. Remote aircraft stands are located at the B- C- and D piers (Figure 9). For boarding and deboarding at a remote aircraft stand, human operators need to conduct a bus@gate procedure. Bus@gate procedure means that an airplane will be positioned and handled at the gate stand location that is not directly connected to the terminal. For arriving flights, this means that passengers and crew cannot enter the terminal directly after landing. Therefore, the passenger route includes a bus that takes passengers from the shuttle bus gate to the airplane for departing flights and from the airplane to a bus injection point (BIP). A bus injection point is a controlled entry or exit point where buses can access the airport terminals and drop off passengers. By minimizing the distance passengers need to travel on foot and optimizing the use of available space at the terminal gates, the bus@gate procedure aims to reduce congestion, shorten transfer times, and enhance operational efficiency (based on internal documents of RSG).

Figure 9 shows an overview of the bus gates and bus injection points (BIPs).

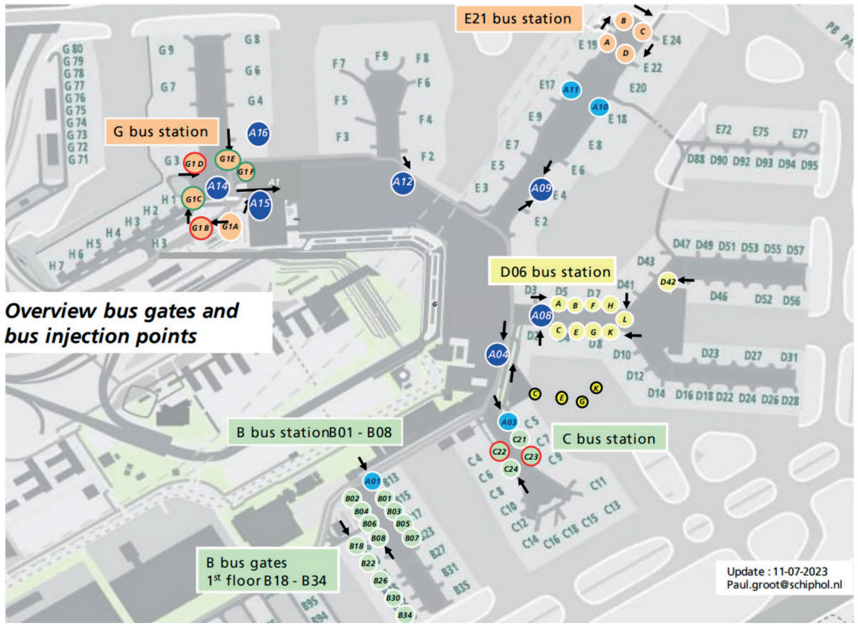


Figure 9: Overview of busgates and bus injection points (BIPs) in Schiphol Airport (RSG, 2020a)

The bus@gate procedure requires logistical coordination between many different actors, namely the airport authorities, cabin crew, ground handling services, and bus drivers.

For arriving flights, the bus@gate procedure starts when the airplane has come to a complete stop, the bus coordinator is present and officially initiates the process. If the operator is not present, the procedure cannot start. After that, the operator checks the stairs and passenger pathway for anything unusual and secures the access door. Then, he or she contacts the bridge connector, who connects the bridge to the airplane. The bus coordinator checks if the bus driver is ready and if the bus is parked at the bottom of the stairs. The cabin attendant opens the main cabin door after the bus coordinator confirmed that the deboarding could begin.

When the deboarding process has started, passengers are directed to designated bus boarding areas at the platform, where they walk from the airplane through the movable bridge section and the fixed stairs down to the platform. A bus is parked at the bottom of the stairs to bring the passengers to the terminal (Figure 10). Passengers are guided onto shuttle buses based on their destination gates. Human operators oversee the lboarding and deboarding of passengers onto buses, ensuring safety and timely departure schedules. When the bus has come to its maximum capacity of 55 passengers, the bus driver gives a signal to the bus coordinator and another bus stops at the platform. Once aboard the buses, passengers are transported directly to the terminal gates, where they can proceed with onward connections or exit the airport. The bus coordinator is responsible for removing tape barriers from the apron. After the deboarding is completed, the process of boarding the next airplane is initiated.

When passengers with reduced mobility are on board, the assistance operator facilitates the assistance of this passenger with an ambulift on the other side of the airplane. A separate assistance bus will transport the passenger to the terminal if necessary.

An overview of the deboarding procedure is presented in Figure 10.

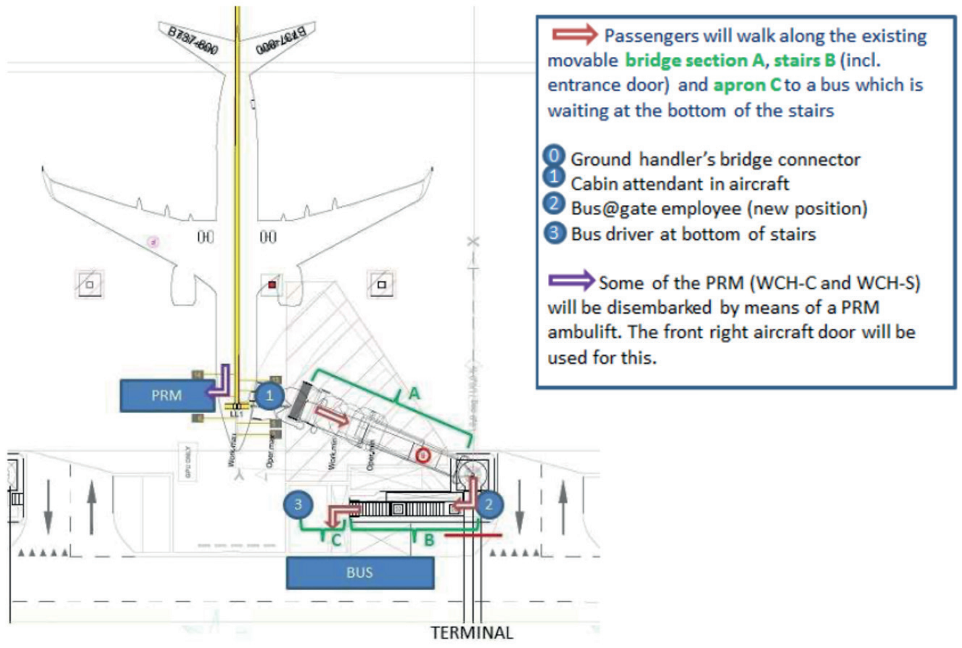


Figure 10: Deboarding procedure (RSG, n.d.)

3.2.3 Key roles

The key roles involved in the boarding and deboarding procedure are identified based on internal documents of Schiphol Airport about the bus operations at the airside. Key roles in the bus operations are the bus director, the bus coordinator, and the bus driver:

- The **bus director** operates from a remote tower and is responsible for the planning and coordination of the bus transport.
- The **bus coordinator** is the eyes and ears of the bus director at the airside, and is responsible for the execution of the bus@gate procedures.
- The **bus driver** is responsible for transporting passengers during boarding and deboarding procedures.

To understand what the roles of these essential human operators involve, who they interact with, and how they intervene with the current bus system, qualitative research has been conducted in the form of shadowing sessions and unstructured interviews (Section 3.3).

3.3 Practitioner's perspective

Before designing future roles of human operators in an autonomous bus system in Schiphol's airside operations, it is essential to better understand the current bus operations. Therefore, this Section serves as preliminary context research to better understand the current different roles of human operators and interactions between each other and the bus (RQ2). This study focuses on the boarding and deboarding procedure at bus gates. While the work procedures of the different roles and other internal documents of Schiphol were a solid base for understanding the context, the small interactions of the human operators with the bus system and the supporting processes were not evident. Therefore, a qualitative approach is conducted, to uncover what the different roles and interactions of the human operators include in practice in the current bus system.

3.3.1 Research design

For this study, the qualitative research method of 'shadowing' is used. Shadowing refers to ethnographic work where the focus of attention is upon the daily practice of a single individual, living and working within a complex institutional social setting (Gilliat-Ray, 2011). It is a suitable method to get a detailed picture of the individual roles, their approach, tasks, and interactions with the environment and others across work teams during a specific and focused procedure, into otherwise invisible aspects of people's lives (Blake & Stalberg, 2009; McDonald, 2005; Sirris et al., 2022). As such, it is suitable for understanding the daily activities of human operators in the current bus system in airside operations. In this study, shadowing shifts have been conducted with different stakeholders, where the real-life work situation of the participants (i.e., 1 bus driver, 1 bus coordinator, and 1 bus director) has been studied during the boarding and de-boarding process.

Before starting the shadow shift, participants were told about the effect that the researcher has on the situation they are researching, called the Hawthorne or observer effect, which can cause issues in shadowing (McDonald, 2005). Based on Burgoyne and Hodgson's (1984) advice, the researcher made explicit that it is possible to discuss the observer effect directly with those being observed. Additionally, the participants are encouraged to think out loud during the shift. The participants were observed during both busy (i.e., boarding and deboarding) and quiet times (i.e., in between arriving and departing flights). The shadow shift included a side tour, the preparation and execution of boarding and deboarding procedures, and participating in breaks in between procedures.

Additionally, unstructured interviews with the same participants were held (i.e., 1 bus driver, 1 bus coordinator, and 1 bus director) in the form of open conversations, to receive in-depth descriptions of tasks and interactions from the participants and to understand their perspectives on the current bus system. The interviews were conducted using a set of themes (i.e., daily tasks, communication methods, unexpected scenarios, and job satisfaction) and took place in person during each shadow shift in between peak moments.

Both the shadow sessions and the unstructured interviews were necessary to create an in-depth understanding of the current bus operations, including individual operator tasks, collaboration with other operators, and interactions with the current bus system.

Paricipants and sampling

Key roles during the current bus procedures were identified (Subsection 3.2.3), which are the bus director, the bus coordinator, and the bus driver. These operators were shadowed during the boarding and deboarding bus procedures because they have the most interaction with the other operators and have a central role in the current bus system. Three shadow sessions were conducted, each with one bus director, one bus coordinator, and one bus driver who operated during the boarding and deboarding procedure. A snowball sampling strategy was used, by initially targeting the bus coordinator manager, who had significant connections within the network of bus drivers and coordinators. This approach ensured that participants were selected from one of the three professions specified and were sampled based on their willingness to participate in the research. For the unstructured interviews, the same 3 participants were selected as the shadow shifts (i.e., 1 bus driver, 1 bus coordinator, and 1 bus director).

The participants must remain anonymous since it allows the participants to speak freely about their experiences and opinions.

Data collection

Each participant was directly observed by the researcher during one shift of 1.5 - 2 hours, by shadowing the participant on the airside or in the tower during the participant's assigned shift. The shadow shift with the bus driver and the bus coordinator took place at the same day. The shadow shift with the bus director followed two days later. The first shadow shift started with the bus coordinator and began at 08.30. The second shadow shift was with the bus driver and started at 11.00. The third shadow shift was with the bus director and started at 15.30. The start of each shadow shift is presented in Figures 11-13.

During the shadow shifts, the researcher made a set of field notes. Based on the procedure's recommendations of McDonald (2005), this included tracking logs of the operator tasks and interactions with a detailed timeline. During the shift, the researcher asked the participants questions about the operator tasks to stimulate them to explain their tasks in rich detail. These answers were also written down in a hardback notebook in the form of notes. After the participants gave permission, photographs were taken of operator tasks and interactions to support the data. The participants were not recognizable in the photographs to ensure anonymity.

The unstructured interviews were conducted in person at the bus coordinator's office (with the bus coordinator), at Tenderplein (with the bus driver), and in the tower (with the bus director) and were held by one researcher. The unstructured interviews were conducted in the form of conversations during the shadow shifts and covered a set of themes (i.e., daily tasks, communication methods, unexpected scenarios, and job satisfaction). Each interview lasted between 15 and 20 minutes.

Data analysis

The field notes were reviewed and organized to identify human operator roles, tasks, and interactions with passengers and the bus system. This process involved a vizualisation of the tracked logs and a detailed timeline, as well as observed behavior and interactions with other operators and the bus. Additionally, photographs taken during the shadowing sessions were examined to supplement the qualitative data with visual evidence of operator tasks and interactions, providing a tangible understanding of the operational context.

The notes of the unstructured interviews were written down during each shadow shift. These insights were used as supportive material to understand and visualize the context of the current bus system.

Figure 12: Start of the shadow shift with the bus driver

Figure 11: Start of the shadow shift with the bus coordinator

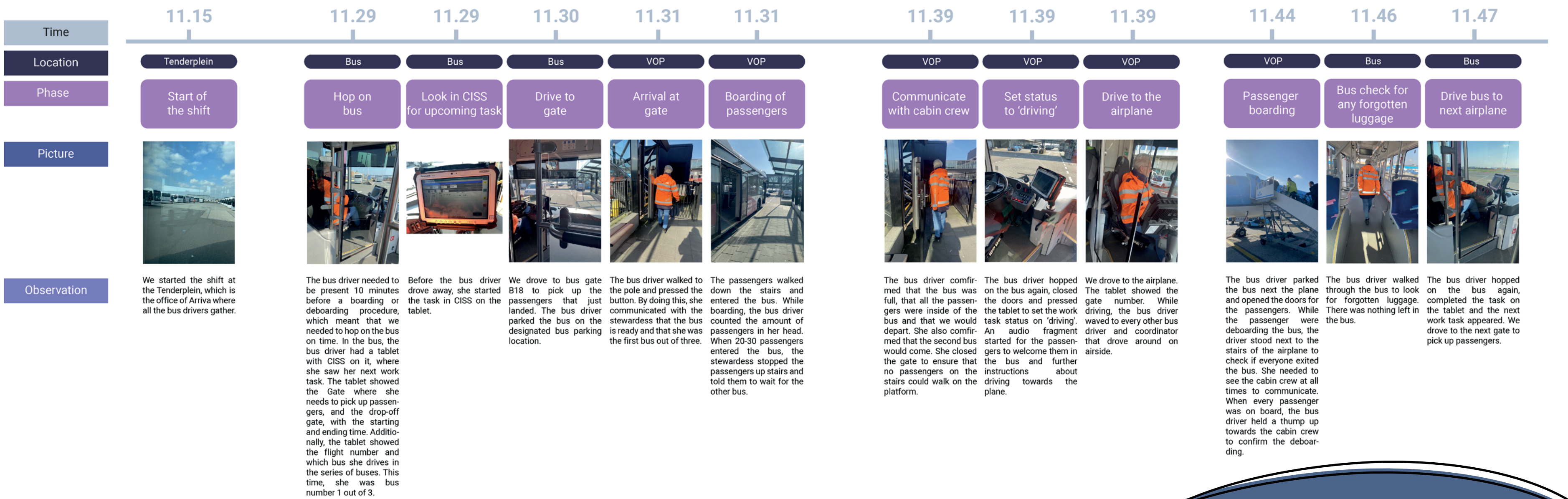
Figure 13: Start of the shadow shift with the bus director

3.3.2 Results

The shadow shifts provided an in-depth understanding of the current boarding and deboarding procedures at bus gates in Schiphol Airport. The insights of the shadow shift with the bus driver are visualized in Figures 14-16. The shadow shift of the bus coordinator is presented in Figures 17 & 18. The insights of the shadow shift with the bus director are shown in Figures 19 & 20. Each participant provided a different perspective on the specific procedure (i.e. the bus driver's, the bus coordinator's, and the bus director's perspective). Based on these insights, a Social Network Analysis (Wasserman & Faust, 1994) map is created (Figure 21). According to Wasserman & Faust (1994), a Social Network Analysis focuses on the interaction of entities in a specific process. In this context, the map shows the relationships between human operators and their communication tools in the current bus system. Additionally, a customer journey is designed to determine the essential steps during the boarding and deboarding procedure at bus gates from a passenger's perspective (Figure 22).

The customer journey forms the base for the service blueprint (Shostack, 1984) (Figures 23 & 24), which aims to create a deep understanding of the underlying processes of the boarding and deboarding procedure, including all the relevant human operators, their daily tasks, interactions with others and the bus system, communication strategies, small negotiations between operators, and deviating scenarios.

Shadow session - Bus driver (boarding)



Key insight: The bus driver is responsible for the communication with the flight attendant that the bus is ready, and counts passengers while they board the bus.

Figure 14: Visualization of the observations made during the shadow session with the bus driver during the boarding procedure (1/3)

Shadow session - Bus driver (deboarding)

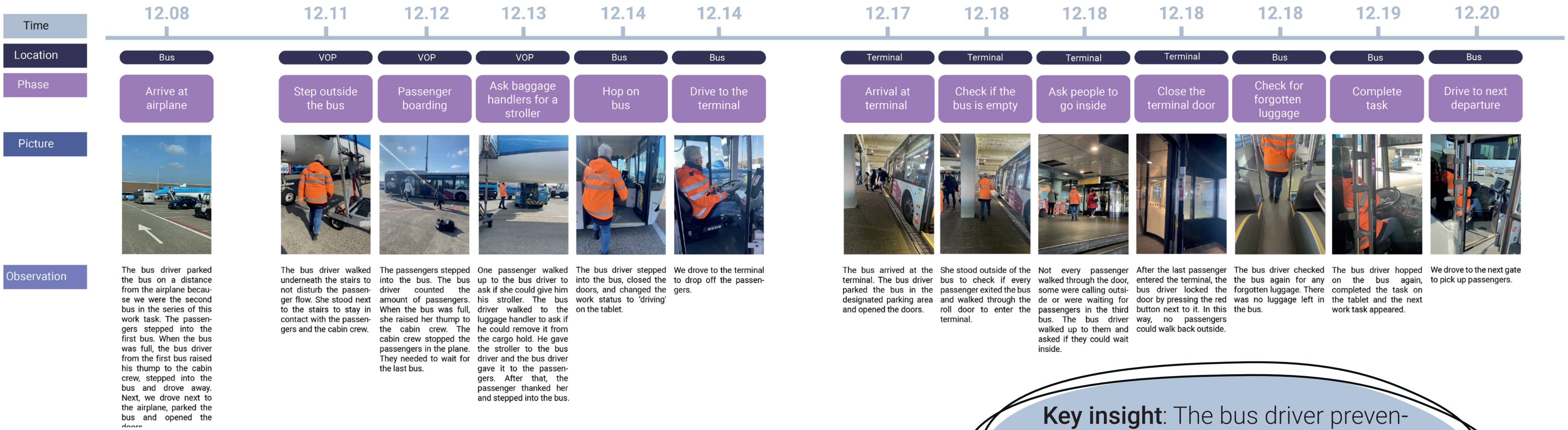


Figure 15: Visualization of the observations made during the shadow session with the bus driver during the deboarding procedure (2/3)

Key insight: The bus driver prevents passengers from walking freely on the platform, checks if the bus is empty, and assists passengers with luggage.

Shadow session - Bus driver (boarding)

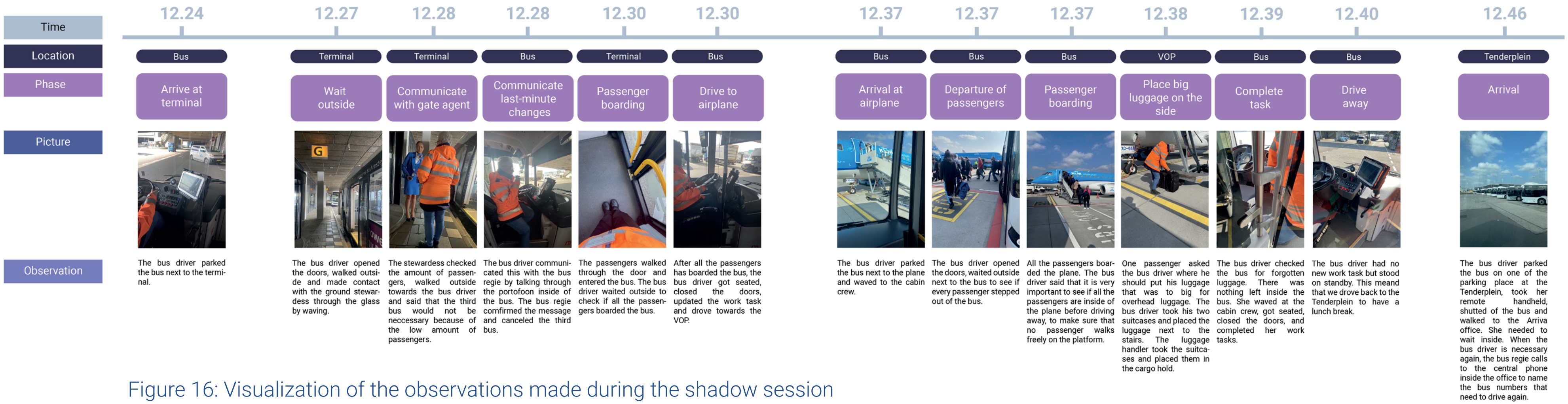


Figure 16: Visualization of the observations made during the shadow session with the bus driver during the boarding procedure (3/3)

Shadow session - Bus coordinator (deboarding)

Bus@gate procedure

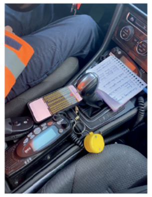
Time	8.30	8.50	8.52	9.00	9.07	9.40	9.55	9.57	9.58	10.13
Location	Door 60	Car	Car	Car	Terminal	Door 60	Car	VOP	Stairs	Bridge
Phase	Start of the shift	Drive site round	Drive site round	Drive site round	Wait when extra support is needed	Coffee break	Drive to airplane	Set up walking path	Wait at gate	Close the entrance to the terminal
Picture										
Observation	The bus coordinator started his shift in his office building at door 60. Inside the office, the schedule is presented of that day, including all the procedures and the present employees. We had 3 bus@gate procedures this day. There were 3 buscoordinators working during the morning shift.	The bus coordinator took his mobile phone with him and got into his car.	The bus coordinator had the CISS planning open at all time to check the gate numbers. He started his remote handheld to be able to communicate with the bus drivers. The communication with the bus regie during the shift was via whatsapp on the mobile phone.	The bus@gate prochedure was later in the day, so we drove around at airside and waited for further instructions from bus regie.	The bus coordinator drove to the B-pier were a lot of bus procedures took place. He checked if all the parking spots were free from other carts and trolleys, such as baggage carts. If for example, there was a trolley from KLM, the bus coordinator would call to that airline to clean it up. But today, no carts were placed in the wrong areas.	The bus coordinator drove back to the office at door 60 and we had a coffee break before the bus@gate procedure would start.	The bus coordinator drove to the designated gate and parked the car next to the bridge.	The bus coordinator placed the barrier tape to create a walking path from the stairs towards the bus.	The airplane has not yet parked at the VOP, so the bus coordinator walked up the stairs towards the gate to wait inside the gate. Meanwhile he had a conversation with the ground stewardesses who were preparing for the next boarding.	When the airplane parked at the VOP, the bus coordinator communicated with the security to lock the door towards the gate. He placed barrier tape next to the stairs to create a path for the passengers from the airplane towards the stairs.

Figure 17: Visualization of the observations made during the shadow session with the bus coordinator during the deboarding procedure (1/2)

Key insight: The bus coordinator is responsible for preparing the deboarding procedure, by placing barrier tape, communicating with bus driver and filight attendant, and glosing the doors to the terminal.

x 3-5 buses

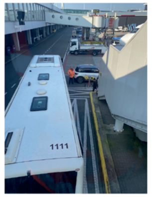
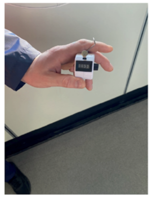
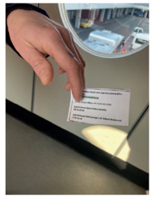
Time	10.19	10.20	10.20	10.21	10.21	10.22	10.22	10.30	10.33	10.34	10.34	10.35
Location	Bridge	Bridge	Bridge	Bridge	Bridge	Bridge	Bridge	Bridge	Stairs	VOP	VOP	Car
Phase	Start bus@gate procedure	Communicate with bus driver	Welcome and count passengers	Communicate with bus driver	Wait for the next bus	Answer questions from passengers	Send people to lost and found	Communicate with cabin crew	Help passenger with less mobility	Remove walking path cords	Complete bus@gate procedure	Drive away
Picture												
Observation	The bus coordinator opened the door to the stairs. He communicated with the cabin crew that the bus@gate procedure could begin.	The bus coordinator looked through the window to see if the bus driver is ready. They waved at each other and communicated through sign language.	The passengers walked out of the plane, downstairs towards the bus. The bus coordinator welcomed the passengers and counted the amount of passengers with a clicker.	When the max amount of passengers has passed, the bus coordinator asked the passengers in the bridge to wait for the new bus. After that, the coordinator raised his hand towards the bus driver to confirm that he could drive away.	The bus coordinator held back the passengers while the second bus arrived.	When passengers had questions, the bus coordinator answered them. ('Can I go to the duty free shop?', and 'why do we need to go in the bus?')	A passengers forgot his jacket. The bus coordinator gave him this card with information about the lost and found.	The bus coordinator walked towards the airplane to check with the cabin crew if all the passengers departed.	The bus coordinatord helped a passenger with small reduced mobility to walk down the stairs to the bus, while assisting her with luggage.	The bus coordinator removed the walking path cords on the platform after the last bus drove away.	The bus coordinator checks if nobody is left inside of the bridge. He closed the door to the stairs afterwards.	The bus coordinator drove back to the office.

Figure 18: Visualization of the observations made during the shadow session with the bus coordinator during the deboarding procedure (2/2)

Key insight: During deboarding, the bus coordinator keeps close contact with the bus driver, holds back passengers when the bus is full, answers questions about forgotten luggage, and assists a passengers with reduced mobility.

Shadow session - Bus director

Time | Location | Phase | Picture | Observation

19.00 — Tower — Start of the shift

We started the shift at the entrance of the tower. The security guard let me in, I received a visitors badge and the bus director picked me up at the entrance. We went to the 10th floor, which is where bus directors are located.

19.05 — Tower — Tour through the tower

The bus director was not yet busy because it was before the evening rush hour. That's why he gave a tour through the tower. During the evening shift, there were two gate planners present who were responsible for assigning the gate to airplanes. Additionaly, there were two apron controllers, who were responsible for the tow trucks, ambulances, and other vehicles. The bus director was on his own during the shift. He was responsible for the bus planning and 40 bus drivers.

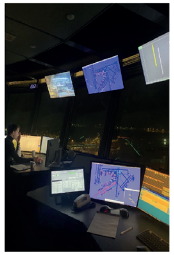
19.10 — Tower — Planning inbound flights

The bus director started with planning in all the buses that are needed to cover the inbound flight rush hour. During the day, there are 4 peak moments when all the KLM city hopper depart or arrive, which all need buses to transport passengers. in total, there are 900 bus movements required per day. Therefore, the bus director planned in the buses in the program OPAS. OPAS is a semi-autonomous planning program, which shows the bus regie a possible planning in light grey. The bus director can make changes and can officially assign tasks to the bus drivers, which makes the tasks light green. The bus drivers can accept the tasks on their screen in the bus, which makes the tasks dark green. During summer, it can be really busy and not all the tasks can be assigned to bus drivers, which causes delay.

19.15 — Tower — Calling bus drivers

The bus director mentioned that the KLM cityhopper outbound has the highest priority in that case. In OPAS, the bus director looked at the flights, looked how many passengers where on each plane, and determined if extra buses where needed or if buses needed to be removed. He mentioned that when it's really hot or cold outside, he would plan in more buses to make sure passengers don't need to wait to long in the bus.
After planning in the buses, the bus regie called the central line to the Tenderplein and named the bus numbers that need to get ready. These bus driver had a stand-by moment/break until the bus director calls them again.

19.20 — Tower — Monitoring

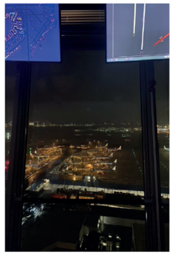


While the airplanes landed contuinuously, the bus director monitored the buses in OPAS to see if buses needed to be assigned to recently landed airplanes. If a flight changed into light blue in the system, this meant that a flight was delayed (i.e., catering is not ready, the cleaning staff is still busy, etc.). Bus drivers can communicate this through their tablet. The bus director then knows that the buses need to wait.

19.30 — Tower — Call from bus driver

A bus driver called the bus director through the central phone. He was frustrated because a flight attendant didn't count the passengers who left the plane. Therefore, the bus driver had no overview if the bus was already full. If the bus director thinks this is worthy to communicate to the airline, he would make a note. This time, he didn't think it was relevant.

19.42 — Tower — Receive bus driver schedule



The bus director received the bus driver schedule for the next morning by email from Arriva. The bus regie downloaded the file and uploaded it to OPAS.

19.49 — Tower — Bus driver is sick

A bus driver called the bus director through the remote handheld. He said he was not feeling well. The bus director canceld his next tasks, assigned it to another bus driver, and put the bus driver on stand-by.

Key insight: The bus regie constantly updates the bus schedules, monitors the operations, and keeps in close communication with the bus drivers and coordinators.

Figure 19: Visualization of the observations made during the shadow session with the bus director (1/2)

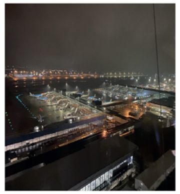
19.51 — Tower

Extra bus needed for KLM

The bus director noticed in OPAS that there were more passengers than expected on the flight. Therefore, he added an extra bus by creating a new tasks. He assigned the tasks to one of the bus drivers that was waiting for a next task. The bus driver accepted this on his tablet. The bus director continued monitoring.

20.02 — Tower

Switch from inbound to outbound fligths



The rush hour was over for inbound flights, which meant all the passengers were deboarded and the Cityhopper flights started their turnaround process. This meant for the bus director, that he had to plan in all the buses for the outbound flights as effective as possible. He didn't want buses to have two boarding procedures after one another. The goal was to always drive with passengers on board by having a boarding and deboarding task consecutively.

20.07 — Tower

Call the bus drivers

After planning in the outbound flights, the bus director called again to the central line from Tenderplein and named 3 bus numbers that needed to start their tasks again to cover the peak moment.

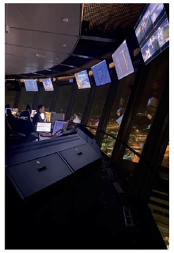
20.09 — Tower

Forgotten luggage

A bus driver called the bus director through the remote handheld and said that a passengers has forgotten her luggage in the bus. The bus director called a bus coordinator with the remote handheld and sent him to the bus to pick up the luggage and bring it to the lost and found. The bus regie texted the bus coordinator afterwards through whatsapp to check if the task was successfully executed.

20.25 — Tower

Two flights at the same gate



A bus driver called the bus regie through the central line and said that there are 4 busses parked at the gate instead of 2. This was because the gate agent from the airline planned in two flights at the same gate but the time between them was too close (one was delayed). This could potentially result in the fact that passengers step into the wrong bus and step into the wrong plane. The bus regie said to the bus driver that passengers needed to wait and communicated with gate planner, who was sitting next to him in the tower. Gate planning decided that flight 1 had priority over flight 2 and communicated this with the gate agent. The bus regie called the bus driver from the first flight and told him that he could open the doors for the passengers. After that, the bus regie called the bus driver from the second flight and told him to driver away and park on the other side of the pier, and wait there.

20.34 — Tower

No gate agent present

A bus driver called the bus director through the central line and said that there was no bus agent present, so the boarding procedure could not start. The bus regie told the bus driver to wait and called the gate agent. The gate agent didn't respond. The bus director called the bus driver back and communicated this information back. The bus driver needed to wait for the gate agent.

20.44 — Tower

No bus is present

A gate agent called the bus director through the central line and said that there is no second bus present at the gate after the first one left. The bus director looked at the cameras on the big screen to see what the current situation was with the first bus. The status of the flight in OPAS showed that the catering was still refilling the plane, so the passenger couldn't board. The bus director set a 10 minute timer. This is because after 10 minutes, the bus with passengers needs to go back to the gate to wait for further intstructions. The bus director called the gate agent back with this information. After 2 minutes, the catering was done and the bus driver opened his doors to let the passengers board the plane.

20.50 — Tower

Other bus drivers on stand-by

The rush hour of the outbound flights almost came to an end. The bus drivers without a next task were put on stand-by, which meant they could go back to Tenderplein to wait for further instructions.

21.00 — Tower

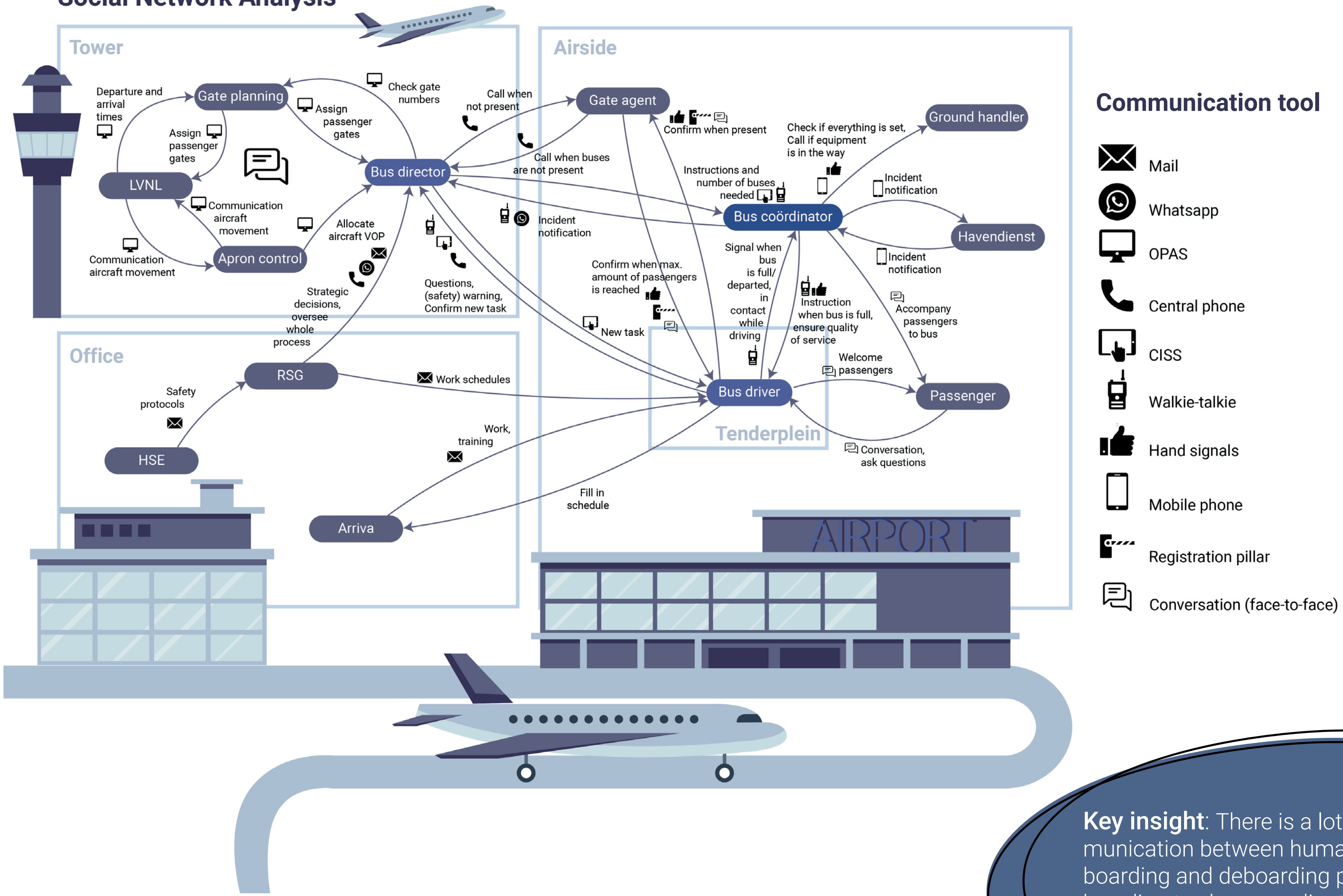
End of rush hour

Rush hour was over. This also meant that the first bus drivers could go home. The bus director wished these bus drivers a nice evening through the remote handheld. The bus drivers responded with the same message.

Key insight: In case of emergency, the bus director needs te remain focused, follow protocols, remains in close contact with the human operator on-site.

Figure 20: Visualization of the observations made during the shadow session with the bus director (2/2)

Social Network Analysis



Key insight: There is a lot of internal communication between human operators during boarding and deboarding procedures. The bus director, bus coordinator, and bus driver play a central role in the operation.

Figure 21: Social network analysis map (Wasserman & Faust, 1994) of the current bus operations. The arrows present the interactions between human operators. The icons respresent the communication tool that is used between operators.

Customer journey during boarding and deboarding

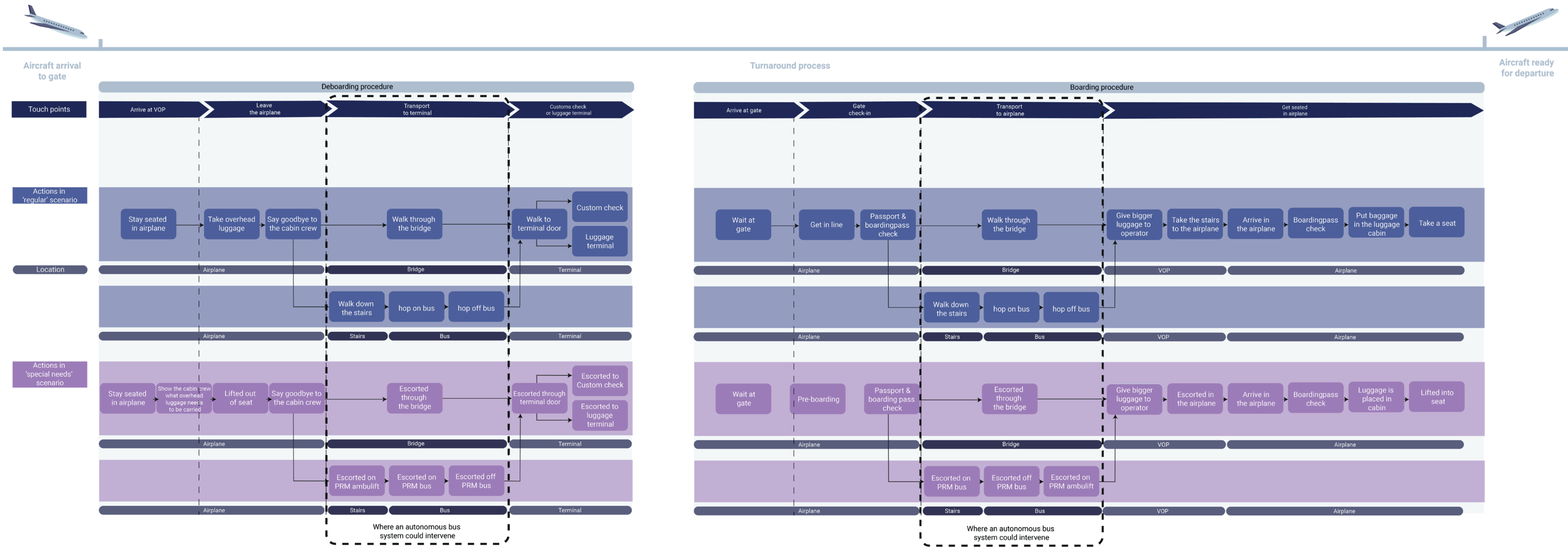


Figure 22: Customer journey from the passenger's perspective, during the deboarding and the boarding procedure

Service blueprint of deboarding procedure

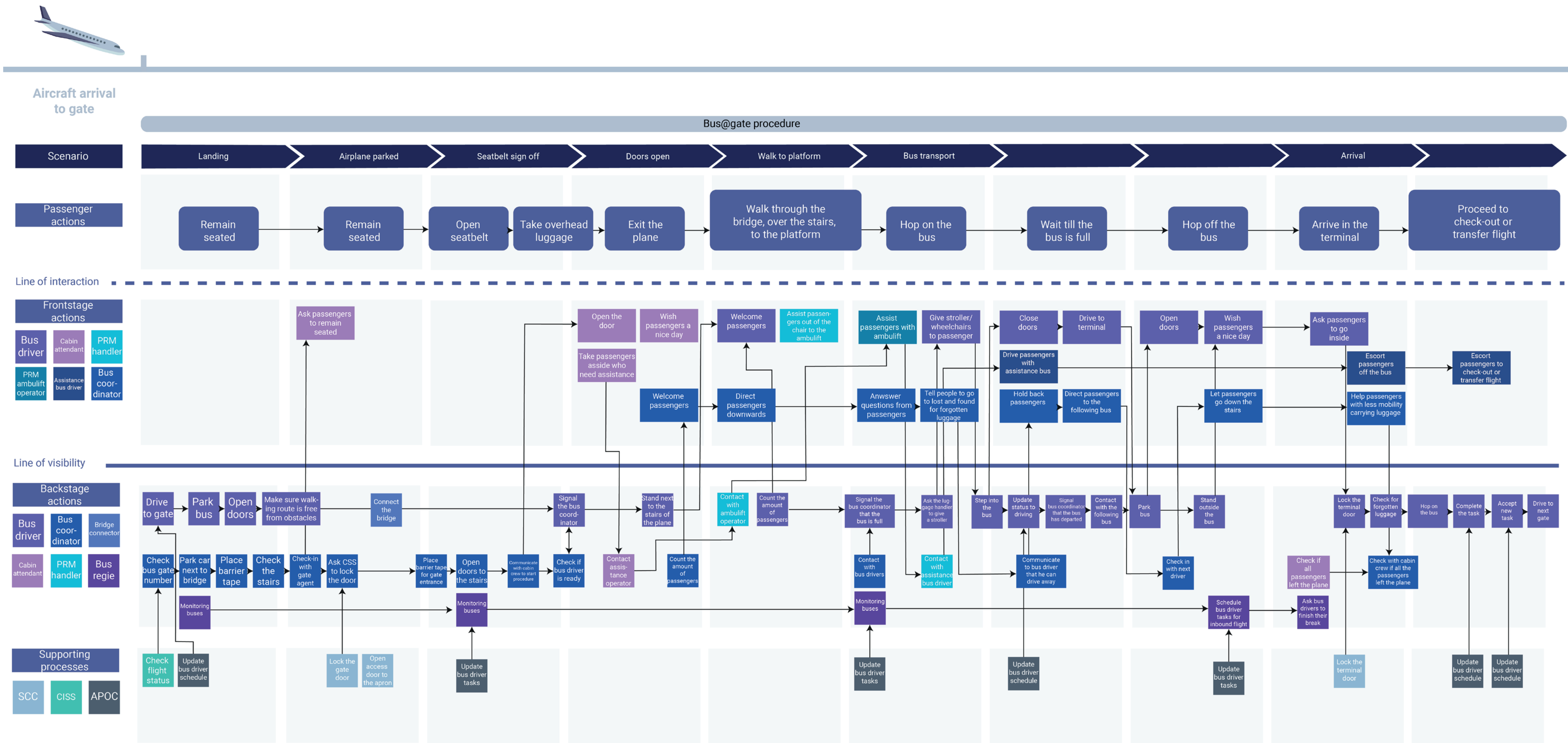


Figure 23: Service blueprint (Shostack, 1984) for the deboarding procedure

Key insight: Human operators play a key role in the direct interaction with passengers, by welcoming them, escorting them to the buses, answer questions, and making sure the passengers go inside of the temrinal or the airplane.

Service blueprint of boarding procedure

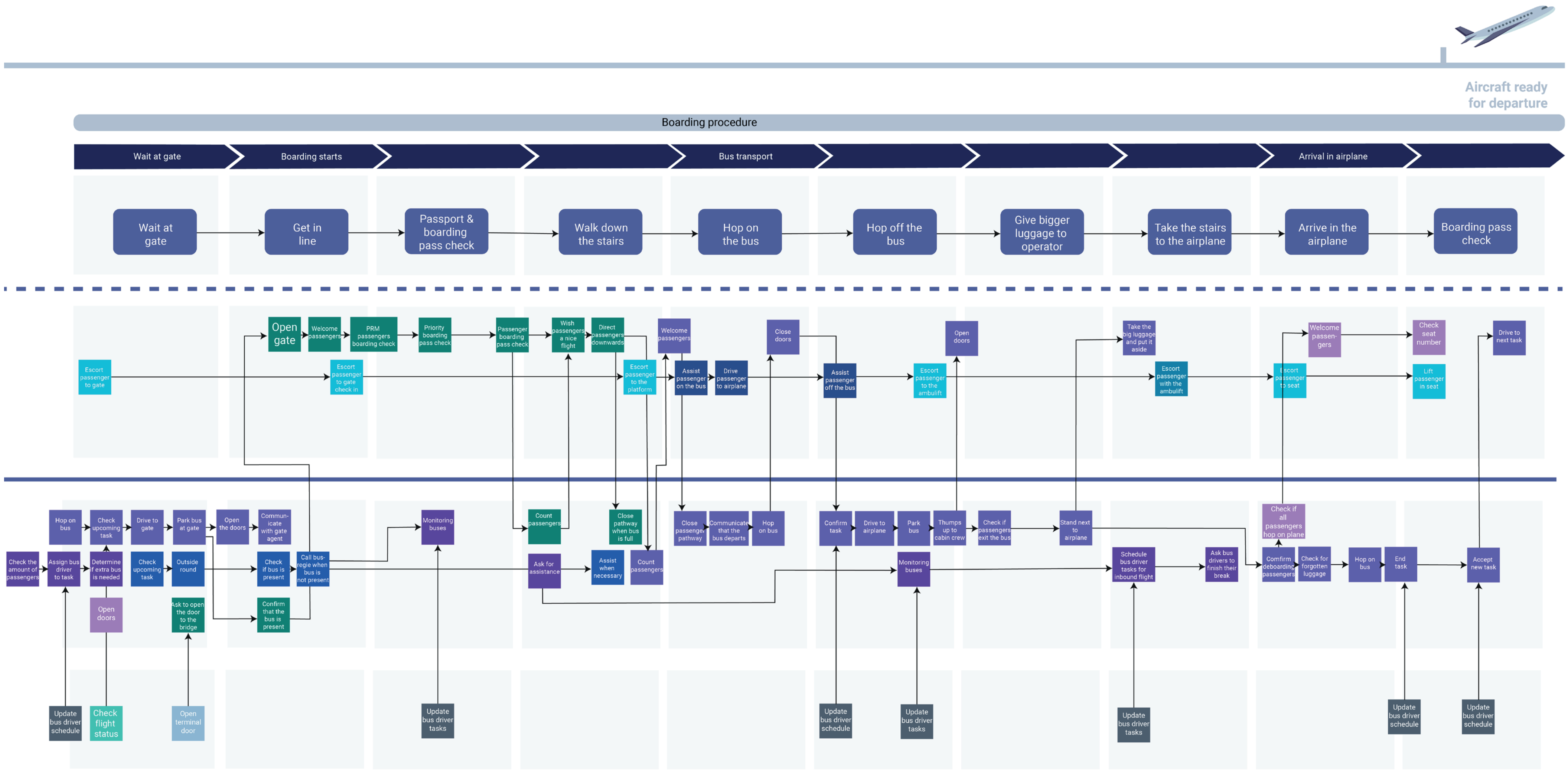


Figure 24: Service blueprint for the boarding procedure

Key insight: Human operators are essential in the execution of backstage processes, such as preparing the walking path, connecting the bridge, and making sure the buses are present on time.

3.4 Key insights

Based on the observations during the shadow shifts, several insights have emerged. This sections serves as a summary of the key insights, based on the shadow sessions, together with the visualizations (i.e., the social network analysis and service blueprint). First, human operators serve as social actors besides their bus-related tasks. For instance, during the shadow shift, the bus driver stood outside and welcomed passengers, took luggage from passengers and placed it next to the cargo hold, asked passengers to go inside the terminal after deboarding, and checked the bus for forgotten luggage (Figures 14 & 15). Additionally, the bus coordinator welcomed passengers who landed, answered questions from passengers while waiting on the bridge, helped passengers to navigate to the Lost and Found, and helped passengers with less mobility by holding their luggage (Figures 17 & 18).

Second, the bus driver and coordinator community is strong, with close relationships between coworkers, where everyone knows each other, and everyone feels like part of a family. During the shadow shifts, it was noticed that every bus driver and bus coordinator waved at each other during an encounter (i.e., driving past each other) at the airside. Additionally, bus drivers and coordinators spend a lot of time with each other in between procedures. During the shadow shift, the bus driver was waiting in the Tenderplein office with approximately 10 other bus drivers, who were playing puzzles together and had all sorts of daily conversations.

"I like it that everyone here is the same. I know almost all the bus drivers by name." *- Bus driver*

"Hi, there goes [bus driver]! *Waves* You should meet her, she will for sure take you with her on the bus." *- Bus coordinator*

Third, driving around, being able to look closely at airside operations, and social interaction are key aspects that contribute to job satisfaction among bus drivers and coordinators. Based on the unstructured interviews with the bus drivers and coordinators during the shadow shifts, these themes were appointed. All the participants expressed negative thoughts when they were asked about the possibility of not driving anymore or remotely in the future.

"When I cannot drive anymore or I need to drive in a simulator, I will quit immediately and will do something else." *- Bus driver*

"I enjoy every workday, driving around with the bus. It gives me freedom and is not stressed at all." *- Bus driver*

Lastly, there is a lot of internal communication between human operators during boarding and deboarding procedures. Bus drivers, coordinators, and the bus director all use the program CISS to check recent updates on bus schedules and gate numbers. CISS stands for Central Information System Schiphol, and it is a central information system owned and managed by Schiphol Airport. It is fed with information forthcoming from other stakeholders like handlers. All this information is inserted in CISS via an interface and/or through direct input. During a procedure, the bus driver communicates with other drivers and with the bus director through the walkie-talkie, to confirm last-minute changes and reassign tasks. The bus coordinator has contact with other coordinators and with the bus director through WhatsApp. On the airside, sign language (e.g., thumps up, counting, etc.) is an essential aspect of the communication between operators. This is used when the buses are full, the number of buses needs to be communicated, or when the buses take off. The bus director communicates frequently with the bus driver, by communicating last-minute changes in schedules to drivers. The bus driver, on the other hand, calls the bus director when they want to express frustration about delays, about gate agents who are not present, or other frictions in the operation.

In conclusion, the context of the current bus system reveals that it entails significantly more processes than just the driving element. Bus drivers, bus coordinators, and the bus director are not only responsible for driving the buses but play a central role in the coordination and execution of the entire boarding and deboarding procedure, serve as a social factor who provides service to passengers, adjusts to unexpected scenarios, ensures safety, and check if the buses are empty, clean, and no luggage is forgotten. So, when introducing autonomous buses, driving tasks will be removed, but the remaining tasks of human operators are considerations to take into account in an autonomous bus system.

4. Expert's perspective

In Chapter 3, we focused on the current bus system, including the tasks and interactions between human operators and the bus system during the boarding and deboarding procedures at bus gates. While the previous Chapter took the perspective of different human operators into account, this chapter investigates the perspective of external experts. To ultimately design the future role of human operators in an autonomous bus system in airside operations, we first need to explore how a future bus system and future human operator roles would be different than the current situation (RQ3). After that, it is essential to understand how experts envision a future autonomous bus system in airside operations. Based on semi-structured in-depth interviews with these experts, responsibilities of future human operators in Autonomous Airside Operations are identified, which forms a base for the ideation phase in Chapter 5.

Aim: The aim of this study is to understand the different perspectives on the future human operator role and how this differs from the current role (RQ3). Additionally, the study aims to understand where and how human operators intervene in a future autonomous bus system in airside operations, which forms the base for the ideation of the future role.

RQ3: What are the different perspectives on the future human operator role and how does this differ from the current role?

Source: photo courtesy of RSG (n.d)

4.1 Introduction

Based on the literature review in Chapter 2, we concluded that understanding human operator roles in autonomous workplaces is context-dependent and requires further investigation for successful implementation (Palanque et al., 2021; Xing et al., 2021). Prior research has mainly focused on post-implementation perspectives and how human operators perceive their roles in autonomous workplaces. However, there is a gap in examining human-centered approaches to designing new roles before the actual implementation of automated systems. This study aims to fill that gap by exploring future human roles in a specific use case, namely a human-centered autonomous bus system, in Autonomous Airside Operations at airports.

The aim of this study is to gain a comprehensive understanding of future human operator roles in an autonomous bus system. We will investigate different perspectives on how these roles will evolve from the current ones and where and how human operators will intervene in a future autonomous bus system within airside operations. This will provide a foundation for ideating future scenarios and roles in Chapter 6.

To explore these perspectives, we are conducting a qualitative study using semi-structured interviews with experts. According to Meuser and Nagel (2009), expert interviews are a type of qualitative interview that focuses on the specific knowledge and insights of experts in a particular field. These interviews are valuable in the early stages of research to gain in-depth insights, especially when access to the field might be very specific or challenging, as is the case with autonomous bus systems. Furthermore, expert interviews can expedite data-gathering processes by leveraging the practical insider knowledge of these experts, who act as representatives for a broader group of stakeholders (Meuser and Nagel, 2009).

The expert interviews are conducted to answer the following research question:

RQ3: What are the different perspectives on the future human operator role and how does this differ from the current role?

The desired outcome of this study is to develop a nuanced understanding of future human operator roles in an autonomous bus system, drawing on the extensive knowledge and experience of experts. Additionally, we aim to gather context-specific insights about future autonomous bus systems in an airport environment, providing a basis for the ideation of future human operator roles.

4.2 Method

4.2.1 Study design

A qualitative study is conducted with in-depth semi-structured expert interviews. The study consists of semi-structured expert interviews with 11 participants who have knowledge of and/or experience with autonomous transportation systems and/or airside operations. The interview consists of three main activities: (1) the experts are asked about their perspectives on the future operator role in an autonomous bus system and how this differs from the current role; (2) the participants are sensitized with the airside context, by presenting them with the current bus operations at airside; (3) the participants envision a future autonomous bus system in the context of airside operations.

4.2.2 Pilot interview

A pilot interview was conducted with one employee from the Innovation Hub. The interview took place online through Microsoft Teams. The aim of the pilot test was to test the technology (i.e., Microsoft Teams, Miro, microphone, video, and auto-transcription software), to test the interview guide, and to evaluate the templates in Miro. Based on the pilot interview, the interview guide was updated with additional questions.

One recommendation was to open the video and templates in Miro before the interview to ensure a smoother flow. Additionally, the employee advised recording the audio as a backup in case the auto-transcription is unclear.

4.2.3 Participants and sampling

This study was granted ethical approval from the Research Ethics Committee at the Delft University of Technology. For the recruitment of participants for the interviews, purposeful sampling and snowball sampling has been used. This ensures that the participants are selected based on one of the following criteria: their (a) experience in the implementation of autonomous transport systems, (b) experience in testing autonomous buses, (c) manufacturers of autonomous buses, and (d) bus system service owners in Schiphol Airport. Research suggests integrating inside and outside experts into one common analytical framework (von Soest, 2023) to maximize thorough reflection on the knowledge, but also identify potential information gaps and personal biases of experts. This resulted in sampling 3 inside expert participants from RSG (i.e., service owners of the bus operations) and 8 experts outside of the organization, who have different roles and backgrounds (e.g., researchers, individuals experienced in implementing autonomous transportation systems, trial initiatives, and autonomous bus manufactuers). An overview of the participants is presented in Table 1. The participants must remain anonymous since it allows the participants to speak freely about their experiences and opinions. A consent form was sent to the participants who wished to take part in the study, which they signed and sent back to the researcher prior to the interview.

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No.	Function	Organisation	Gender
P1	Solution architect	RSG	Male
P2	Advisor smart & green mobility	Municipality	Male
P3	Founder	public-private partnership organisation	Male
P4	Head of Reasearch & Development	Autonomous bus manufacturer	Male
P5	Program Manager Smart Mobility	Harbour	Male
P6	Founder	Autonomous bus start-up	Male
P7	Teamlead Sales Engineer	Autonomous bus manufacturer	Male
P8	Safety Driver	RSG	Female
P9	Bus Service Owner	RSG	Male
P10	Business Developer	Autonomous bus manufacturer	Male
P11	Advisor Smart Public Mobility	Consultancy	Male

Table 1: Demographics of the participants for the expert interviews

4.2.4 Tools

- Informed Consent forms (Appendix A)
- Interview guide (Appendix B)
- Microsoft Teams
- Audio-record equipment
- Audio-transcription software
- Video compilation of the current bus operations, used as sensitizing material (Figure 25)
- Simplified version of the current bus system in Miro (Figure 26)
- Empty template for a future autonomous bus system in Miro (Figure 27)
- Notebook and pen
- Quiet reserved space

4.2.5 Procedure

The main researcher conducted the semi-structured interviews, which were held online via Microsoft Teams. These sessions were audio-recorded and automatically transcribed using WhisperAI transcription software. Each interview lasted between 50 and 60 minutes and followed an interview guide detailed in Appendix B. Additionally, a Miro board was used to display a simplified version of the current bus system (Figure 25) and an empty template for a future autonomous bus system (Figure 26). Interviews were conducted in Dutch for Dutch-speaking participants and in English for the other participants.

The session began with the main researcher asking the participants to introduce themselves. Following the introduction, the researcher provided a brief overview of the research, explaining the interview's purpose, and structure, emphasizing the anonymity of the outcomes and participants' right to withdraw at any time.

After the introduction, the semi-structured interview questions were asked. The interview consisted of three parts. The first part aimed to understand the participant's experience with autonomous bus systems and gather their perspectives on the role of human operators in such systems.

In the second part of the interview, the context of the airside is introduced. The goal of the second part of the interview was to sensitize the participants to the airside context and to understand the perceived opportunities and challenges of an autonomous bus system implementation. To sensitize the participants, two prompts were used: a video showing key tasks of different human operators (i.e., bus driver, bus coordinator, and bus director), created by the researcher using clips from Schiphol publications (Figure 25), and a simplified Social Network Analysis map (Wasserman & Faust, 1994) based on Figure 20, illustrating current airside operations and relationships between stakeholders (Figure 26).

In the third part, participants elaborated on future interactions between human operators and autonomous buses in airside operations by designing a future bus system. They used an empty Social Network Analysis template to outline the roles and interactions in the future system (Figure 27). The outcome included an overview of touchpoints where human operators would intervene in the future autonomous bus system. Examples of filled-in templates by two participants are shown in Figures 28 and 29.

The interviews ended with the main researcher inviting participants to share any additional thoughts or questions. The interviews ended with the main researcher thanking the participants.

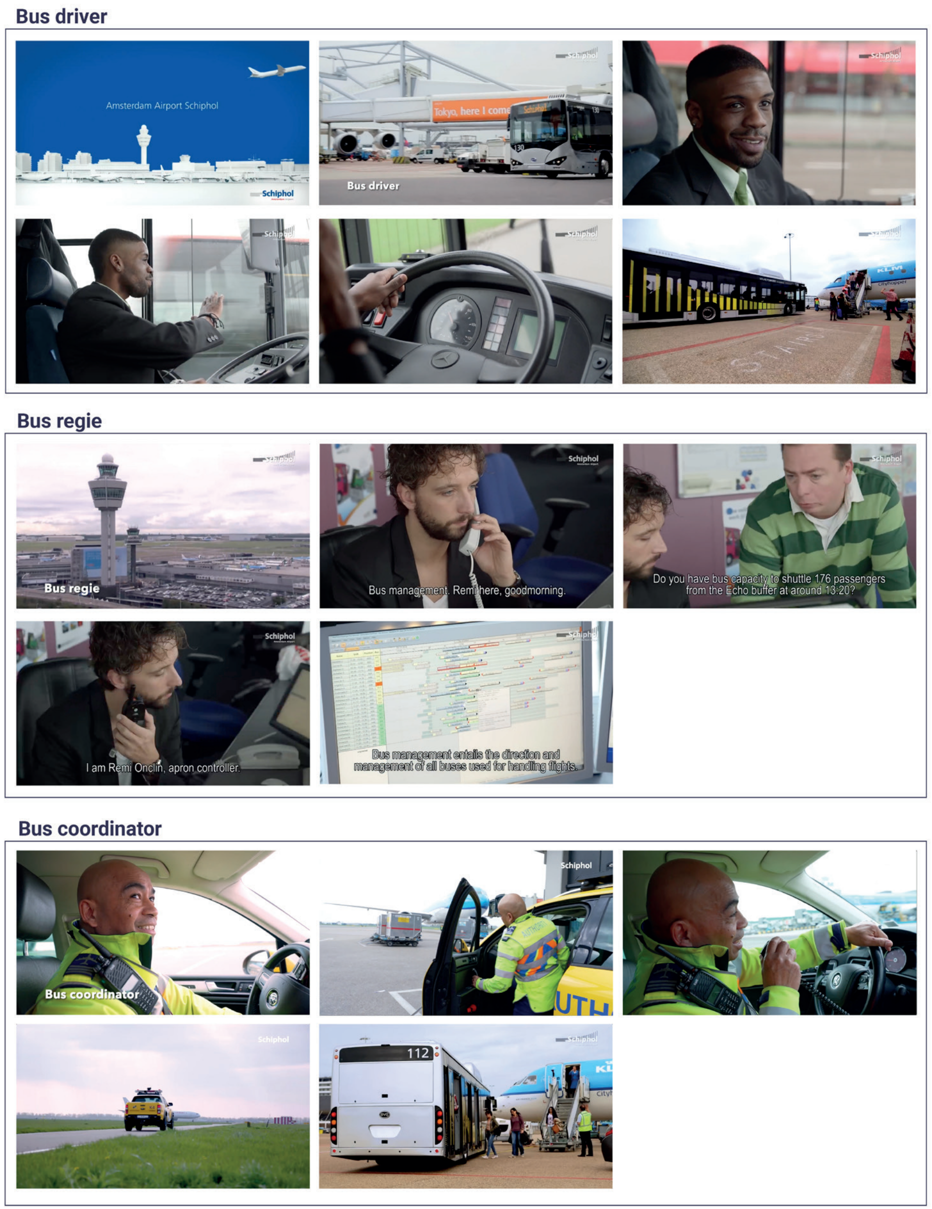


Figure 25: Frames of the video compilation of human operators (i.e., bus driver, bus coordinator, and bus director) which was used as a prompt during the expert interviews

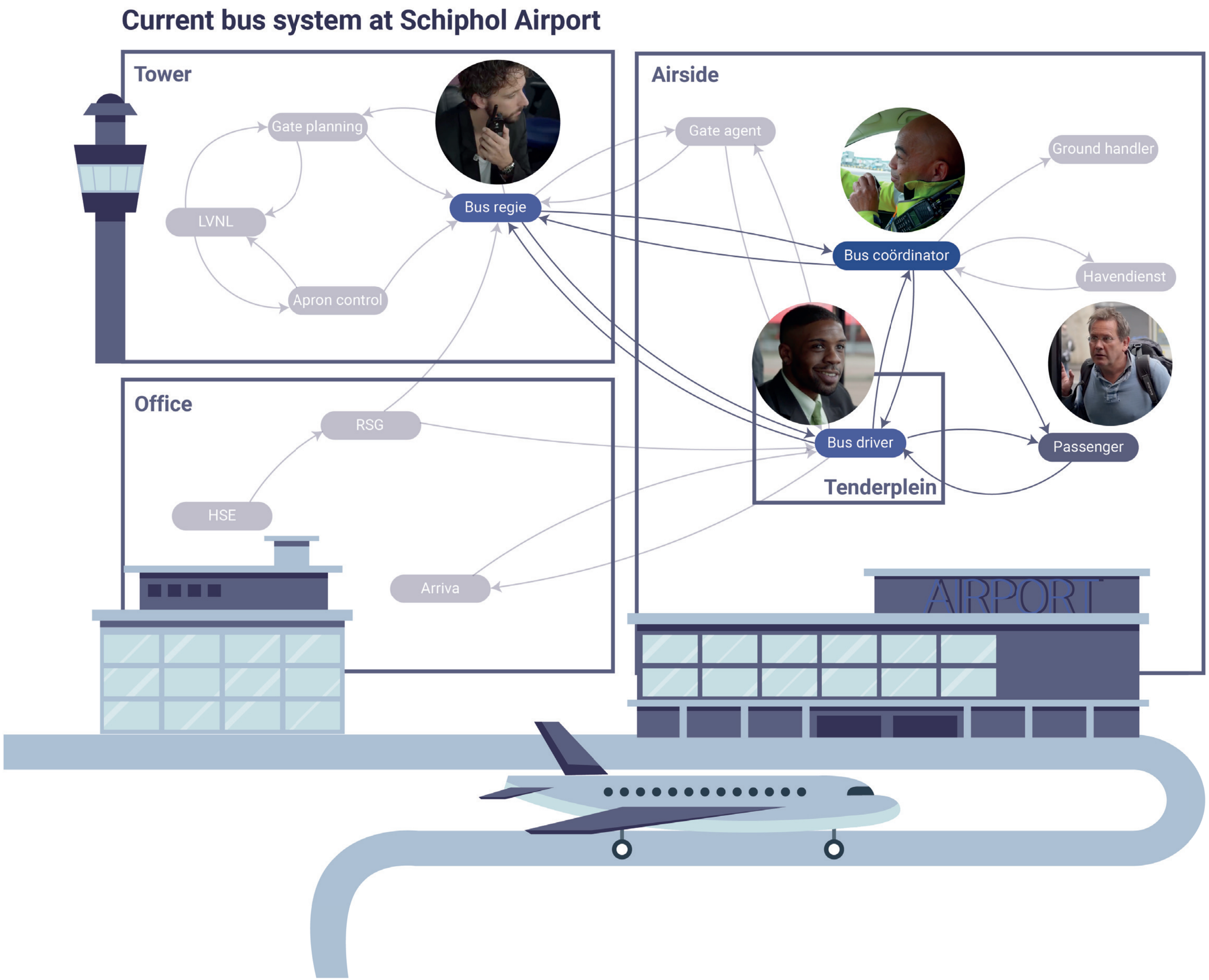


Figure 26: Simplified version of the current bus system (prompt)

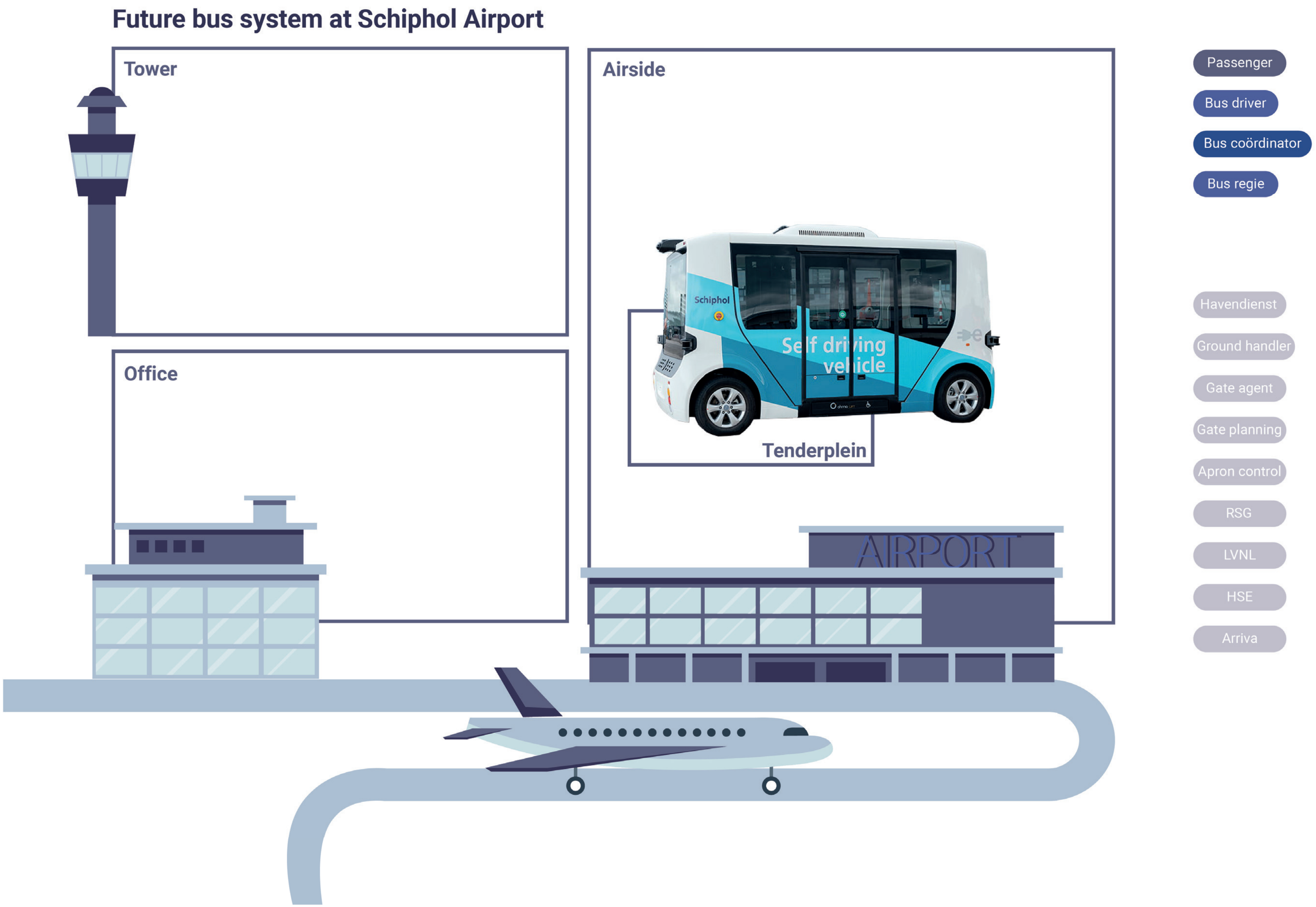


Figure 27: Empty template for a future autonomous bus system (prompt)

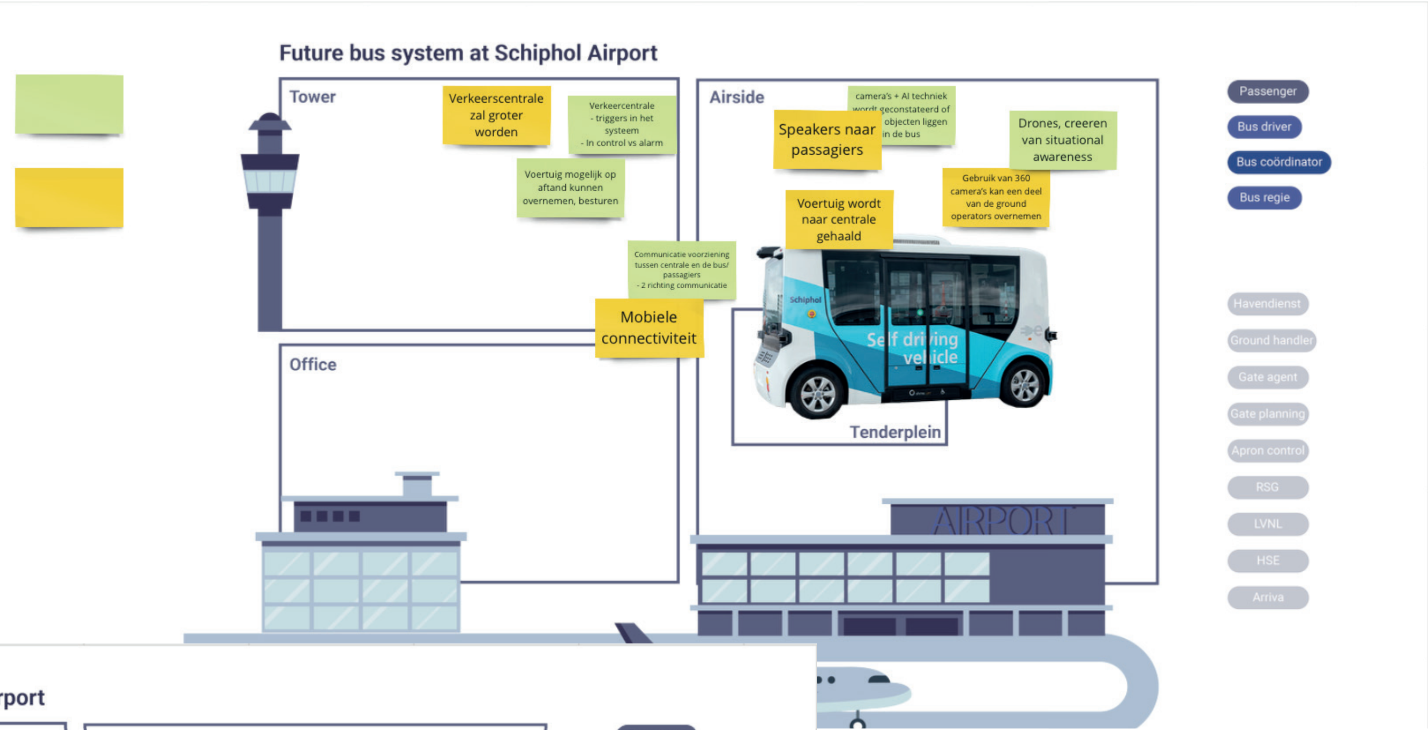


Figure 28: Example 1 of a filled in future bus template

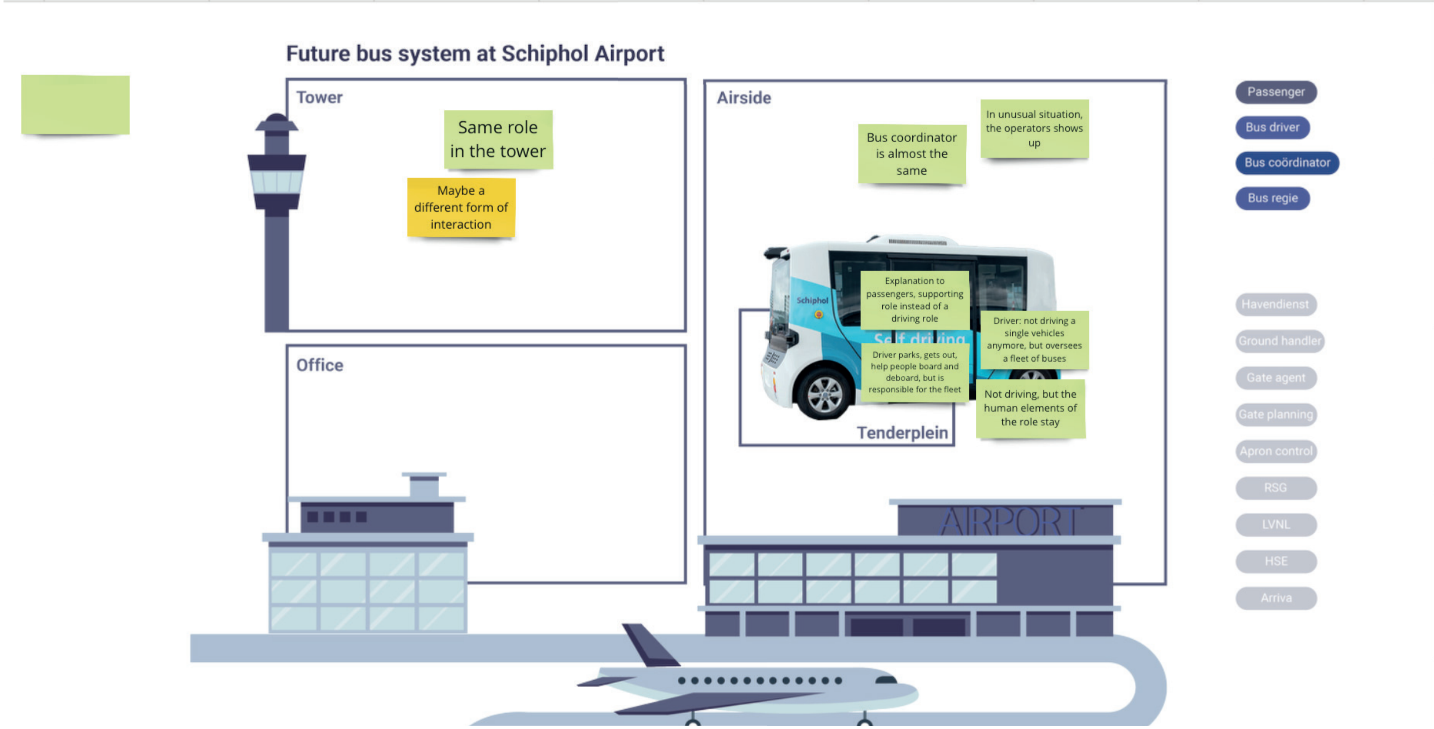


Figure 29: Example 2 of a filled in future bus template

4.2.6 Data collection

The interviews were audio-recorded using two devices and automatically transcribed with Microsoft Teams and WhisperAI software. In practice, the main researcher guided the conversation and filled in the Miro template as participants spoke, rather than having them do it themselves. Some participants viewed the interviews as potential sales conversations for future collaboration with RSG. There was a strong emphasis on the implementation of an autonomous system and system-level reflections, rather than focusing on the human-centered framework, including the roles, tasks, and interactions of human operators. As a result, the researcher often had to redirect the conversation back to human aspects instead of technical details. Additionally, participants, being experts in their own fields, sometimes struggled to relate to the airport context. However, the video (Figure 24) and the simplified map of the current bus system (Figure 25) helped make their responses more specific and tangible, rather than general.

4.2.7 Data analysis

The data was analyzed using reflexive thematic analysis. With reflexive thematic analysis, Braun and Clarke (2013) refer to acknowledging and reflecting on how the researcher's own background, biases, and experiences may influence the analysis process and interpretation of data. In line with this form of thematic analysis, an inductive approach was taken. According to Braun and Clarke (2013), the analysis is not shaped by existing theory but is often used to understand participants' experiences and perceptions.

Data analysis is conducted by the main researcher. The data is analyzed according to the following workflow based on the work of Braun and Clarke (2013):

- Eliminate errors in the auto-transcription
- Read the full transcription (familiarization)
- Start coding across the entire dataset by grouping quotes in codes and code groups
- Search for themes and sub-themes
- Review themes and sub-themes
- Define and name themes
- Write and finalize the analysis

The data analysis was done using the analysis software Atlas.ti. Initial codes were developed by the main researcher, wherein labels were assigned to sections of text. This was conducted in a bottom-up approach, using open coding, rather than predetermined themes or a theoretical framework. After this, iterative axial coding was used, where initial codes were combined, reorganized, and connected to form larger categories. From this, themes and sub-themes were developed and reviewed. The themes were defined and finalized, as presented in the coding tree (Figure 30).

4.3 Reflexivity

As the primary researcher, I acknowledge that my background, experiences, and personal biases influence the research process and the outcomes. With a background in Industrial Design focusing on mobility, my understanding and interpretation of participants' responses are shaped by this perspective. It is important to recognize that my positioning may have introduced biases, particularly in the types of questions and follow-up questions I posed to the experts, as well as in how I interpreted the data and identified themes.

Prior to each interview, informed consent was obtained from all participants, ensuring they were fully aware of the research objectives, procedures, and their right to withdraw at any time. Anonymity and confidentiality were maintained, and participant quotes were used anonymously in the reporting of results. Given the sensitivity of discussing future roles in autonomous systems based on participants' individual experiences, I created a respectful and open interview environment, allowing participants to feel comfortable pausing or stopping at any time.

To facilitate discussions on potential future scenarios and roles in Autonomous Airside Operations, I provided support information in the form of a video and templates. While these templates may have introduced biases by familiarizing participants with key roles in the current bus system, they were essential for offering background knowledge on current bus system operations, including human operator roles. This was crucial for participants to provide concrete and tangible answers about future human operator roles in the airside context, despite potentially limiting their creative freedom.

To ensure the credibility of the research and minimize researcher bias, participants with diverse backgrounds (e.g., bus service owners, researchers, individuals experienced in implementing autonomous transportation systems, trial initiatives, and autonomous bus manufactuers) were sampled. Additionally, an external confirmability audit, conducted by the thesis supervisor, provided critical feedback on the process, data, and intermediate results, in line with Bryman & Bell's (2007) guidelines.

4.4 Results

In this section, the extracted themes generated from the qualitative study are discussed to answer the research question (RQ3): *What are the different perspectives on the future human operator role and how does this differ from the current role?* The codes were grouped into themes and a coding tree was assembled (Figure 29). With this approach, five main themes were extracted: (1) Human operators are responsible for ensuring safety in the airport's highly regulated but complex multi-stakeholder environment, (2) Human operators need to adapt to working alongside an autonomous bus implementation, (3) Human operators are crucial in scenarios where the autonomous bus system reaches its limitations, (4) An autonomous bus system requires on-site human intervention and remote supervision, and (5) Having human roles to enhance passenger experience and control passenger behavior. In this Section, identified themes and sub-themes have been given a description. Quotes are added to clarify the themes, translated from Dutch to English. Almost all the data was included in the themes.

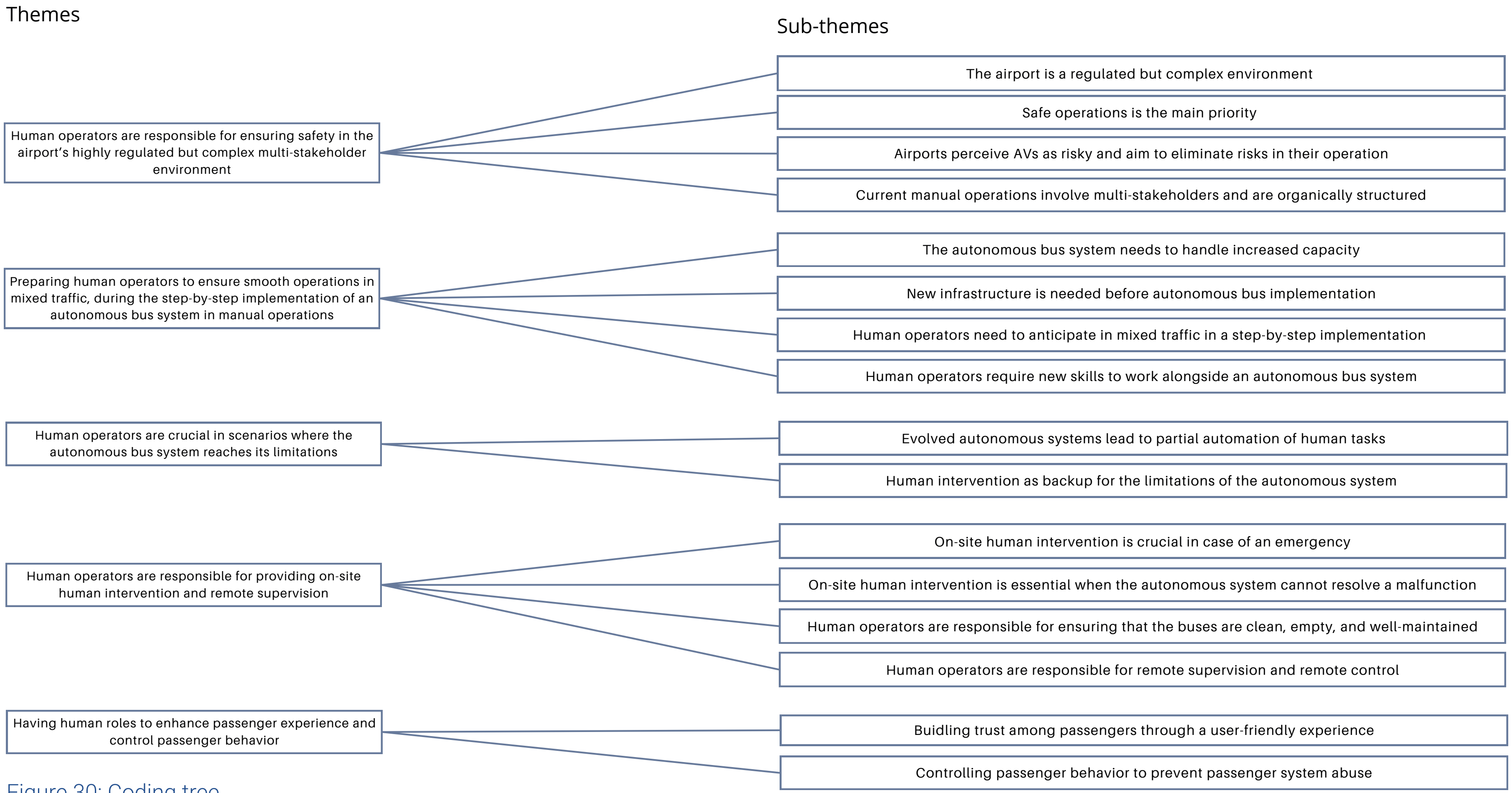


Figure 30: Coding tree

4.3.1 Theme 1: Human operators are responsible for ensuring safety in the airport's highly regulated but complex multi-stakeholder environment

Experts assumed that an airport is a regulated bus complex environment for the implementations of an autonomous bus system. On the one hand, they mentioned that a highly regulated environment could be an opportunity to successfully implement the autonomous bus system because of various reasons. first, operating within a regulated private environment affords airports more flexibility in terms of laws and regulations, such as speed limits (i.e., the maximum speed limit at Schiphol Airport is 30km/h).

"When you are in a controlled environment such as Schiphol or on a very large factory site, you of course do not have to deal with public laws and regulations." *(P11)*

Second, the highly regulated environment of airports establishes a structured setting where scenarios and risks are minimized. Third, other road users at the airport are employees, who are trained and who must adhere to rules of conduct, unlike road users on public roads.

"With normal buses, you just have a lot of other road users such as pedestrians, cyclists, and the risk thereof. Here [Schiphol Airport], you have a closed area where you actually have all kinds of predictable behavior." *(P2)*

However, despite the regulated nature of the environment, participants mentioned that challenges persist in the successful implementation of autonomous buses. This is because participants characterize the current operational environment by intensive traffic, involving different actors and vehicles, and the lack of infrastructure.

"I mean it's quite complex as well, it involves many different stakeholders. And also lots of different key roles to be taken into consideration." *(P10)*

After showing the sensitizing material of the current bus operations at Schiphol Airport, the majority of the participants mentioned that the current manual operations are organically structured, including lots of manual procedures and interactions. Implementing an autonomous system could impact this organic structure.

"While it is now a very organic system and people can interact with each other very organically, automatic vehicles will not be able to do that." *(P6)*

Because of the multi-stakeholder environment and intensive traffic, the majority of the experts acknowledged that safe operations at an airport should always be the main priority, by guaranteeing safety for passengers and others on the airside, which requires human operators.

"The most important thing is safety. Schiphol must always be able to guarantee safety for passengers and others on airside." *(P3)*

One expert mentioned that this does not apply to other regulated environments such as a harbor, where goods are transported instead of passengers. This is why human operators remain crucial, to conducting a double check of the autonomous system during operations.

During the implementation of an autonomous bus system, participants emphasized the importance of maintaining safety while dealing with failure. Unwanted scenarios might occur, such as opening the doors of the bus at the airside in case of emergency, which results in passengers walking freely on the platform. Airports need to have human operators to immediately react to unsafe scenarios by having predetermined protocols.

Experts often mentioned that a human operator on board would be necessary, who plays a critical role in mitigating potential risks and ensuring that safety standards are upheld throughout transit. This role could be gradually reduced when an autonomous bus system is more evolved.

"I would say, you could still need someone on board, but only for like real safety reasons, because if there is no one on board people will run freely and maybe in a really hazardous way." *(P10)*

One participant also mentioned the need to have established cybersecurity, to prevent people from hacking the buses and taking over control.

Participants often acknowledged that the public transportation sector, including the airport, is a conservative market. As safety is the main priority, taking risks by investing in AVs is not desirable. Additionally, people working in this sector hold onto nostalgic feelings and do not know what to do with AVs.

"It is quite difficult to prepare for autonomous vehicles. People in the public transport sector don't really know what to do with this. And it is especially difficult for professionals to realize that it is really a solution to the climate challenges we face." *(P11)*

This results in cautious purchasing behavior by public transport organizations, such as airports.

"We are also going to buy old fashioned as a company. I really don't understand it." *(P9)*

Experts also shed light on the fact that different autonomous vehicles (e.g., personal cars, taxi services, mini shuttles, and buses) are in the early stages of development, which is why organizations are hesitant to invest in these initiatives. Currently, the mini shuttles have a lot of exposure in the market, but especially the bigger buses are still at the beginning. Different participants acknowledged that RSG is already doing a good job by aiming to be a disruptive innovator to meet sustainability goals in 2050.

4.3.2 Theme 2: Preparing human operators to ensure smooth operations in mixed traffic, during the step-by-step implementation of an autonomous bus system in manual operations

Experts emphasized to prepare for increased capacity and the need for a new infrastructure. It was pointed out that to accommodate future capacity needs, the airport must invest in future operations now. Participants raised doubts regarding the feasibility of the existing autonomous shuttle buses, which are half of the size of manual buses in current operations, due to their limited capacity. They emphasized the need to operate with more and bigger buses to reach future capacity goals. However, participants expressed confidence that in a reliable and fully autonomous system, it would be feasible to operate more shuttles with reduced spacing between them, thereby enhancing passenger transport capacity.

"You see that buses will be able to drive closer together as soon as they drive autonomously. And you will also see that it [the system] is ultimately reliable and can accommodate more passengers without a driver than with a driver." *(P11)*

The majority of participants agreed on the necessity for new infrastructure before the adoption of an autonomous bus system, to minimize mixed traffic of autonomous buses in manual operations. The interpretation of this new infrastructure varied, ranging from additional road markings, the installation of beacons, adjustments to speed limits, the designation of multiple lanes, and the implementation of roadblocks.

Some participants advised to separate traffic flows and create a separate lane for autonomous buses, to eliminate a mixed traffic scenario. This would result in faster implementation of an autonomous bus system but would decrease flexibility in the operations and remove the need for safety drivers. Furthermore, one expert suggested that separate lanes could also facilitate the use of automated guided vehicles.

When separating lanes would not be feasible participants all mentioned the importance of anticipating mixed traffic, by stating that an abrupt transition would not be possible from manual to fully autonomous operation. Therefore, human operators remain crucial to ensure smooth operation in mixed traffic. A common concern raised by most participants is the non-human driving behavior of autonomous buses, which often leads to frustration and reckless driving behavior among human operators. Participants with experience in other mixed traffic environments proposed giving priority to autonomous systems over other traffic as a resolution. One participant highlighted that external communication from the autonomous bus towards human drivers is necessary to have smooth operations in mixed traffic.

In mixed traffic, experts emphasized minimizing unnecessary movements by human operators in a mixed traffic scenario. Unnecessary swarming of vehicles and human operators could have adverse effects on the environment, and safety, and would disrupt automated systems. Therefore, having human operators in fixed positions would be favorable.

"That staff at an airplane would do the handling, instead of an operator having to drive back and forth in a car. That seems a bit redundant to me." *(P1)*

Although some experts expressed a preference for transitioning from manual to fully autonomous operations, all the participants reckoned that a fully autonomous system would not be possible soon. Therefore, it requires a step-by-step implementation approach, where human operators work alongside this implementation.

"It is a step-by-step process. This means that there will certainly be a form of mixed traffic in the transition process, with initially very few autonomous vehicles, and many manual vehicles. That ratio may change in the future and may ultimately exclude one species. But it is precisely that transition phase that is actually the most complex." *(P5)*

One participant emphasized the gap between theory and reality. During implementation, encountering context-specific challenges will be inevitable, such as a loss of GPS. Experts highlighted that implementation is not something to be rushed. It was advised to rather pursue autonomous system development within a simple use case while accepting the presence of the current manual operation. A proposed strategy was to initially use autonomous buses as an addition to the current manual operations, gradually phasing out the manual buses once the system matures.

To accommodate this step-by-step implementation of an autonomous bus system, experts additionally mentioned a transition in the roles of human operators. As existing roles will transform, it is important to provide training for employees to be reclassified.

First, participants foresaw a transition from in-vehicle drivers to different external specialists, handling tasks such as maintenance, software developments, and updates, creating new employment opportunities.

"Yes, the challenge lies in transferring tasks that the safety driver still has, task by task, to the bus directors or the people at the plane, or at the gate." *(P11)*

Additionally, employees need to feel comfortable with working with new technologies. Some experts expressed concerns that human operators might feel unprepared while working with automated systems. Based on one participant's experience as a safety driver, initial anxiety towards working as a safety driver was common, due to the complexity and novelty of the technology.

"Because quite a few things went wrong in the first few weeks. Then I thought, what have I gotten myself into? What if I'm standing here alone on the bus, and if something goes wrong again, then I have to solve it. I wasn't scared, But I didn't feel very chill." *(P8)*

Participants emphasized that no technical background is required for employees, but the operator rather needs organizational and social skills and needs to be willing to learn new things. Additionally, having experience with an autonomous transportation system is beneficial, and in the case of the safety driver, a driver's license is still required. One participant who worked as a safety driver, appreciated on-the-job learning in the actual bus instead of a simulation, while experiencing real-life problems, learning how to solve complex situations and what to do in case of emergencies, and learning how to manually drive with a joystick. Experts mentioned that over time, employees will become more confident in working with automated systems, resulting in enhanced performance.

In addition to training on utilizing automated systems, participants acknowledged the importance of teaching employees the new codes of conduct. Participants mentioned that employees are a controlled group, who are receptive to clear instructions. Providing employees guidance on what to do in case of emergency is essential according to participants.

4.3.3 Theme 3: Human operators are crucial in scenarios where the autonomous bus system reaches its limitations

Participants acknowledged that further development of an autonomous bus system would result in partial automation of human tasks.

"So the shuttle can take over step-by-step tasks of the human operator, I think. But people have to get used to it. And of course, I think there's an in-between phase needed. So, for the beginning, I would say this human operator still needs to do the same, but step by step I think his tasks can be reduced." *(P7)*

They envisioned a future where automation would enable buses to autonomously reset and navigate towards the maintenance area after self-identifying a malfunction. Moreover, autonomous bus scheduling would be possible, whereby the system can determine optimal bus allocations and adjust schedules dynamically in response to delays. However, experts assumed the bus system still needs human supervision, particularly to intervene manually and to manage last-minute changes.

Participants acknowledged that the integration of autonomous systems would enhance staffing efficiency, particularly as autonomous technology matures. While human operators remain essential during the initial implementation phase, a gradual reduction in their role over time was envisioned. Experts acknowledged that it would be possible to operate more vehicles with fewer drivers, by operating one fleet instead of one bus. Additionally, it was suggested to use ground marshals for assistance, instead of having a separate role. The supervisory job would probably be lightened when scheduling would become autonomous.

Participants did see the importance of reducing the number of human operators because of health issues associated with working in airport environments, personnel costs, and the current shortage of bus drivers in The Netherlands. However, two participants mentioned opposition from labor unions toward this development.

Also, the integration of automated systems with other interconnected systems is mentioned. One participant noted the potential for the system to connect with systems from alternative airports, facilitating autonomous gate planning and bus scheduling.

Additionally, the increased usage of both interior and exterior cameras would partially reduce the number of tasks performed by human operators. Interior cameras could enable remote supervision within buses, ensuring safety, monitoring passenger behavior, and identifying objects that remained inside the bus, such as forgotten luggage. These cameras would be able to scan abnormalities, triggering alerts for human operators.

"I could imagine, if you look at such a bus in 10 years, that it will have a system in it that checks when everyone has gotten off, whether there are still objects on the bus so that the bus can automatically announce something." *(P11)*

However, experts mentioned that this approach requires extensive training data to successfully rely on the system.

Lastly, one participant mentioned the prospect of using drones to create situational awareness but acknowledged the possible impracticality in an airport context.

Nevertheless, participants highlighted that the existing automated system falls short of being completely feasible for daily airside operations. It lacks the capability to fully make independent decisions. While a fully autonomous system may be suitable for quieter environments, it remains impractical for navigating dense, mixed-traffic areas. Experts often acknowledged that an autonomous system always has its limits.

"It's not completely 100% feasible for the moment because there are many different specific contexts where the bus can stop. For example, if there is an obstacle or something on the path." *(P10)*

One participant foresaw that the system might not work one day. Therefore, human operators should always function as a backup mechanism.

4.3.4 Theme 4: Human operators are reponsible for providing on-site human intervention and remote supervision

Experts agreed on the necessity of having human operators available to intervene in case of emergency. When an unusual situation occurs, human operators need to bear the responsibility for ensuring safe operations. Passengers prefer talking to an actual human during times of distress. Participants differed on the mode of communication towards passengers, ranging from voice assistance for minor incidents to immediate physical presence for major emergencies. Voice assistance might not suffice in providing enough support during malfunctions.

Not only in case of emergencies but also in daily operations, human operators play a crucial part. Experts envisioned scenarios where autonomous systems are unable to solve issues such as when the bus is dirty or when a physical malfunction occurs, highlighting the need for manual human back-up processes.

"Of course, a lot is possible, such as software updates and things like that. But ultimately, in a certain situation, manual support may still be required to get the system back into operation." *(P5)*

Additionally, participants stressed the importance of manual transportation for passengers with special needs or in exceptional situations, such as delays. Lastly, experts mentioned that it is not favorable to double autonomous bus capacity to accommodate peak demand. Therefore, having manual operations to cover the peak moment would be more feasible.

Even though participants agreed on the necessity of human operators in an autonomous bus system, they foresaw a phased elimination of the driver's role and a reduction of human operators physically present on buses. While some experts mentioned that the driver role would be fully eliminated, others proposed retaining a human operator in either individual autonomous buses or entire fleets, assuming a more service-oriented role. Some participants suggested enhancing the skills of current drivers for remote driving and autonomous monitoring.

However, on-site human support would be continuously essential. experts highlighted the importance of a human operator in facilitating smooth boarding and deboarding procedures. They emphasized the importance of having a human operator for different reasons, to prevent unauthorized passenger movement on the apron, check if every passenger boards and deboards the bus, prevent incidents like passengers getting stuck between the doors, and assist with luggage handling.

Furthermore, participants emphasized the importance of human operators in ensuring that the buses are empty, clean, and well-maintained. Passengers could make buses dirty by eating on the bus and by leaving behind litter. Apart from cleanliness, on-site engineering is important. Engineers would be responsible for daily inspections, minor maintenance tasks, and software updates. Some participants questioned whether these responsibilities could eventually be delegated to operators standing at fixed locations at the terminal and ultimately to cameras and sensors.

Additionally, experts emphasized the necessity of human operators physically attending to buses to resolve malfunctions. They cited examples such as bus resets, road barrier adjustments, retrieving forgotten luggage, and providing reassurance to passengers.

"If there is no safety operator on board, I would suggest that as soon as there is an emergency someone goes straight to the bus to help people." *(P10)*

Technical expertise was not perceived necessary to conduct small maintenance tasks, but interpersonal skills would be essential for interacting with passengers, ensuring their comfort, and answering questions, particularly given the novelty of the technology.

Besides on-site support, all experts stressed the necessity of human supervision in an autonomous bus system, preferably located in a control room. They mentioned that it is not possible to simultaneously monitor all aspects of the system, but suggested alert-based notification from the system. Initially, more operators would be required to monitor the system. However, as the system matures, fewer operators will be necessary. Experts recommended a phased approach to multi-vehicle tracking, gradually increasing the responsibility of monitoring more vehicles simultaneously.

In case of an emergency, human intervention is perceived as highly crucial. It is necessary that the human operator receives an alert and assesses the situation. The human operator needs to understand the context of the problem and its underlying cause. They stressed the importance of familiarity with different protocols for unusual and complex scenarios. The majority of the experts agreed that crucial decisions, such as opening the doors of the bus, selecting appropriate protocols, dispatching additional human operators to physically go to the incident, and initiating resets, should be made by human operators. Additionally, experts agreed on the necessity for operators to communicate with the passengers inside the vehicle using the intercom. They mentioned that existing communication protocols among human operators are very organic, which needs to be reconsidered when integrating an autonomous system.

Additionally, it is favorable to reset the system remotely and autonomously if possible.

"In tram systems, they have someone behind the screen making decisions and checking that everything is OK. That will be the same for us [autonomous shuttle manufacturer]. No one on board, but someone behind the screen taking care of several shuttles and maybe making a go-no-go decision. Like if the shuttle stops, you will decide if it can restart again." *(P10)*

While some advocated for remote resets whenever possible, emphasizing the importance of having a backup option in case of manual intervention, others expressed reservations. On the one hand, participants mentioned that it is not favorable to have remote control because of the perceived risk and the difficulty of solely relying on cameras. On the other hand, they mentioned that it could always remain an option, with varying degrees of control, such as through joystick operation or limited functions like braking, acceleration, or parking.

When working alongside an autonomous bus system, the perceived working conditions and required skills varied among the experts. First, participants highlighted the significance of technical comprehension. While some participants mentioned that having technical expertise is a must to devise solutions when an error occurs or initial remote control, others mentioned that understanding the cause of an error is necessary, without an immediate need to find a solution. Perception of technical knowledge varied among experts, ranging from understanding algorithms, system processes, outcomes, and operational rationales, and knowing when to trust autonomous systems.

Second, experts expressed concerns about the heightened pressure on human operators, particularly during peak moments. They mentioned that at the beginning of implementation, no human operator has the knowledge since it is all new for them. This initial unfamiliarity puts pressure on human operators. Especially at first, human operators should fully focus on monitoring multiple buses and need to be ready to possibly intervene, which is a complex task.

"Of course, we had the other safety driver who stopped. And she said that it was all too difficult, so I think you need someone who is either open to learning new things or who indeed understands technical things like that a little faster because it can be quite a lot." *(P8)*

However, some experts also foresaw that the job could become monotonous and boring when nothing happens.

Lastly, participants often acknowledged that they had unrealistic expectations regarding working with automated systems. One participant noted the exaggerated 'hype' about AVs a decade ago, forming the public perceptions of those portrayed in science fiction movies. As a result, they mentioned a disconnect between public expectations and current technological capabilities, emphasizing the importance of re-calibrating expectations during system implementation.

4.3.5 Theme 5: Having human roles to enhance passenger experience and control passenger behavior

Experts mentioned that passengers hold a skeptical attitude towards an autonomous bus at the beginning because passengers are often tired, inattentive, and do not use autonomous buses frequently. Creating a user-friendly experience is therefore essential, with a human operator being physically present.

"You have to partly replace the drivers with people who accompany the passengers. I certainly think that if you use such a system for the first year, you really need to have enough people to guide passengers because it is all new for those passengers." *(P11)*

Participants expressed the need for a service-oriented role, that supports passengers, answers questions, explains the technology, and assists during emergencies. This role requires other qualities than a current bus driver. However, the location of the human operator differs among participants. Some mentioned that having an operator inside the bus is essential to earn the trust of passengers. Others mentioned having someone standing next to the bus.

Additionally, to earn the trust of passengers, the majority of the experts mentioned that autonomous buses need to operate without hiccups because passengers expect a working system. Repeated failures will provoke irritation, lead to a lack of trust among passengers, and can result in bad worth of mouth advertisements.

Additionally, participants' attitudes toward the passenger trust development differed. While some assumed that passenger trust develops rapidly, also because taking the bus would be a necessity in the case of the airport context, other participants highlighted that passengers are hesitant towards this new technology, emphasizing the slow process of trust-building. A factor that impacts passenger trust development is the openness to new technologies, which varies depending on the type of passenger.

After passenger trust is achieved, experts mentioned that the assistive human role can be reduced. Alternatively, passengers receive guidance through a voice assistant onboard the bus, thereby preventing them from forgetting their luggage and providing clear instructions on where to stand and proceed. In this case, it should not be necessary for a human operator to accompany the autonomous buses.

However, in case of an emergency, participants highlighted the passengers' need to receive immediate reassurance by human operators, that everything will be resolved, especially in airside operations. According to experts, the situation needs to be clearly explained, including the cause of the incident, the protocol, and the solution. Therefore, a human operator should have direct interaction with the passengers through voice assistance, to enable two-way communication during emergencies and remote resets.

"I think it is useful to either have a video call or someone who can come on the intercom and say that everything will be alright. That there is reassurance that someone is monitoring it so that passengers always know that they are in good hands and that it is safe." *(P8)*

Nevertheless, they did not agree on whether it should be the human operator who oversees the autonomous system, the gate agent, the cabin crew, or another service-oriented operator, such as the assistance operators in the terminal.

Besides enhancing passenger experience, human operators remain crucial for controlling passenger behavior. Experts highlighted that passengers are an insecure factor in an autonomous system, which causes a variety of unexpected scenarios.

"When you talk about the human factors in such a system, I find the passengers in particular quite an uncertain factor. In the sense of, I think that a lot of situations will arise that you have never anticipated in advance, what passengers will do with such a bus." *(P1)*

Therefore, it is important that passengers recognize that they are being monitored. On the one hand, to make people feel safe and reassure them that someone could interrupt remotely when necessary. On the other hand, to minimize system abuse by passengers. Participants foresaw that passengers will not follow the protocol when there is no operator physically present and will test the boundaries of the technology. One expert experienced an instance where passengers positioned themselves in front of the exterior cameras, which prevented the bus from departing. The expert did acknowledge that this might not be the case in a highly regulated environment like the airport.

Lastly, passengers could create unexpected scenarios by leaving things behind on the bus, such as luggage. This would be difficult to manage with systems only.

One solution for controlling passenger behavior is to educate passengers on the boarding and deboarding protocols, including clarifying that it is an autonomous bus. However, the executive strategy differed among the experts. Some recommended using instruction videos in the terminal boarding, while others would not perceive this as a necessity. Others suggested having automatic instructions inside the bus, about fastening the seat belts and instructions about leaving the bus. However, not every passenger would pay attention to this, so backup operational processes are needed.

4.5 Conclusion

In conclusion, human operators will remain crucial in a future autonomous bus system in airside operations, though their roles will be different from the current bus operation. Currently, human operators are responsible for driving the buses, assisting with boarding and deboarding procedures, ensuring safety, and overseeing the manual bus operation. In the future, human operators will transition toward various new roles.

First, human operators remain crucial to ensure safety in a regulated and traffic intense airport environment. The majority of the experts acknowledged that safe operations at an airport should always be the main priority, by guaranteeing safety for passengers and others on the airside, which requires human operators. Especially in a mix of autonomous and manual operations, ensuring safety is essential.

Second, human operators are responsible for ensuring smooth operations in mixed traffic, during the step-by-step implementation of an autonomous bus system in manual operations. As a result, human roles undergo a transition from in-vehicle drivers to different external specialists, handling tasks such as maintenance, software developments, and updates, creating new employment opportunities. Human operators need to feel comfortable with working with new technologies, by providing additional training if necessary.

Third, human operators remain crucial in scenarios where the autonomous bus system reaches its limitations. Experts often acknowledged that an autonomous system always has its limits. Therefore, human operators should always function as a backup mechanism and need to adapt to unexpected scenarios.

Additionally, a future autonomous bus system requires on-site human intervention and remote supervision, which will be executed by human operators. On-site human intervention includes, ensuring a smooth boarding and deboarding procedure, resolving malfunctions on-site, providing face-to-face service in case of an emergency, and ensuring that the buses are empty, clean, and well-maintained. Remote supervision includes monitoring the system from a control room, assessing alert-based notifications, understanding the context and the cause of the problem, following safety protocols, and communicating with passengers in the bus. Additionally, remote contorl over the bus is preferable, depending on the situation.

Lastly, human operator are essential in enhancing passenger experience and in controlling passenger behavior. Participants expressed the need for a service-oriented role, that supports passengers, answers questions, explains the technology, and assists during emergencies. This could enhance passenger trust in autonomous buses. Additionally, controlling passenger behavior is necessary to minimize passenger system abuse.

Ultimately, while the integration of autonomous technology will change the nature of their work, human operators will continue to play a crucial role in maintaining safety, efficiency, and reliability in autonomous airport operations.

5. Design brief

This chapter provides the design brief of the project. Section 5.1 shows a summary of the research insights. Based on the key insights drawn from the literature study, context study, and in-depth expert interviews, a summary of the design challenge is formulated (Section 5.2). Additionally, a focus is set for the project and a design brief is formulated (Section 5.3). The design brief involves the design goal, design function, relevant stakeholders, context of use, and design methods, which will be used to develop a design in Chapter 6.

Aim: Converging the insights of the literature study, context study, and expert interviews into the design brief for future human operator roles in an autonomous bus system.

Source: photo courtesy of RSG (2024)

5.1 Summary of insights

This section provides an overview of the insights based on the literature in Chapter 2, the context study in Chapter 3, and the expert interviews study in Chapter 4. A visual representation of the insights is presented in Figure 31.

5.1.1 Literature study

Successful adoption of autonomous systems is hard for organizations because innovations of autonomous systems are mainly technology-driven and **human factors are subordinated**, which results in poor autonomous system design (Parasuraman & Riley, 1997; Dietvorst & Bharti, 2020).

Literature shows that humans remain essential in an automated system. However, the role of human operators will change (Bradshaw et al., 2013). The interpretation of human operator roles in autonomous workplaces is **context-dependent** (Palanque et al., 2021) and requires further exploration for successful implementation (Xing et al., 2021). Therefore, there's a need for a **human-centered approach** in designing automated systems to ensure they are successfully adopted by human operators and organizations.

Prior research focused on the evaluation of human operators after the implementation of automated systems in their workplace. Studies show that **lack of trust in autonomous systems, misunderstanding of autonomous systems, the responsibility gap between humans and autonomous systems, a decreasing level of decision-making, and loss of control** negatively influence how human operators perceive working with automated systems (Höddinghaus et al., 2021; Lee, 2018; Panchal, 2023; Chu et al., 2023; Langer & Landers, 2021; Raji et al., 2020). However, these studies focussed on the post-implementation of automated systems and have not addressed the proactive redesign of work roles to accommodate automation, which is necessary for the succesful adoption of automated systems by human operators and organizations.

In designing future roles, traditional models like the **Job Characteristics Model from Hackman & Oldham** (1976) become less applicable as automation shifts the nature of work, meaning that it is essential to adopt other methodologies in designing future roles in automated systems.

Prior work focussed on exploring alternative frameworks for the design of future roles. Fox (2023) used **speculative design** to gather nuanced, context-specific feedback on automated systems. This approach aligns closely with human-centered design principles and ensures that the human roles successfully spport the automated system. Speculative design is widely used to explore future scenarios to understand human-computer interaction (Ling & Long, 2023; Grafström et al., 2022) and the future of work (Yams & Munoz, 2021).

5.1.2 Context study

The context of the current bus system reveals that it entails significantly more processes than just the driving element. Introducing autonomous buses will remove driving tasks but will not eliminate the need for human operators, who still play critical roles in: **(1) coordinating and executing the entire boarding and deboarding procedure; (2) serving as a social actor, providing service to passengers; (3) ensuring safety; (4) adapting to unexpected scenarios; and (5) checking if the buses are clean, empty and no luggage is forgotten.**

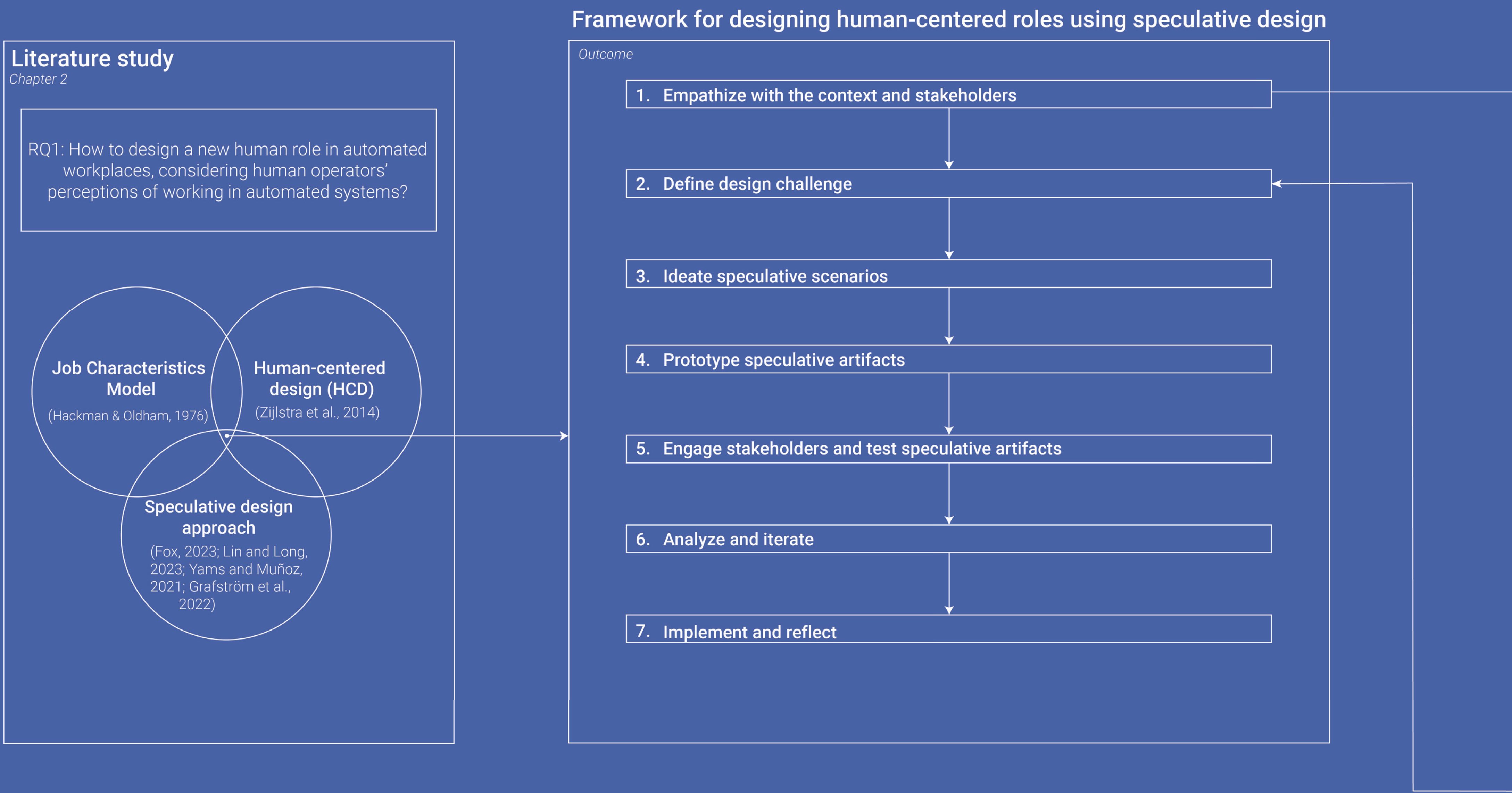
Understanding these roles in scenarios where human operators remain essential in an autonomous systems is crucial for successful implementation.

5.1.3 Expert interviews

Based on the expert interview study, 5 themes can be identified, which show future human operator responsibilities in Autonomous Airside Operations: **(1) Ensuring safety in a regulated and traffic-intense airport environment; (2) Ensuring smooth operations in mixed traffic, during the step-by-step implementation of an autonomous bus system in manual operations; (3) Operating in scenarios where the autonomous bus system reaches its limitations; (4) Providing on-site human intervention and remote supervision; (5) Enhancing passenger experience and control passenger behavior.**

5.1.4 Conclusion

Figure 31 presents a visual overview of the approach and the outcomes of the literature study, the context study, and the expert interviews study. In the expert interviews, the interviewees anticipated a transition towards an evolved autonomous bus system but acknowledged that human operators would still be crucial in scenarios where the automated system has its limitations. This conclusion is reinforced by the literature review, which indicates that humans remain crucial in an autonomous system. However, the literature shows that the implication of the human operator role is context-specific and requires further research. Additionally, observations during shadow shifts with current human operators revealed that while driving tasks would be removed with the implementation of an autonomous bus system, the need for human operators would persist. These operators would still play critical roles in coordinating and executing the boarding and deboarding procedure, providing passenger service, ensuring safety, checking if the buses are empty, clean, and no luggage is forgotten, and adapting to unexpected scenarios. Based on the expert interviews, additional future responsibilities include ensuring safe and smooth operations in mixed traffic, operating in scenarios where the autonomous bus system reaches its limitations, providing on-site human intervention and remote supervision, and enhancing passenger experience and control of passenger behavior. It is necessary to further identify these scenarios where the autonomous bus system requires human intervention and to design future roles for human operators within these contexts.



tasks, (c) Expert interview study outcomes, showing future human operator responsibilities in Autonomous Airside Operations, (d) Design challenge.

Context study

Chapter 3

RQ2: How do human operators interact with the current bus system in airside operations?

Outcome

Current human operator responsibilities, besides driving-related tasks:

- Coordinate and execute the boarding and deboarding procedure
- Serve as social actor who provides service to passengers
- Ensure safety
- Adapt to unexpected scenarios
- Check if the buses are empty, clean, and no luggage is forgotten

Expert interview study

Chapter 4

RQ3: What are the different perspectives on the future human operator role and how does this differ from the current role?

Outcome

Future human operator responsibilities in Autonomous Airside Operations:

- Ensure safety in a regulated and traffic intense airport environment
- Ensure smooth operations in mixed traffic, during the step-by-step implementation of an autonomous bus system in manual operations
- Operate in scenarios where the autonomous bus system reaches its limitations
- Provide on-site human intervention and remote supervision
- Enhance passenger experience and control passenger behavior

Design Challenge

The challenge is to design future roles for human operators that address scenarios where human intervention is required in an autonomous bus system during the boarding and deboarding procedure at bus gates in Autonomous Airside Operations.

5.3 Design brief

The design brief is formulated based on the WWWWWH method (Zijlstra et al., 2014), to understand the project's context and to lay a solid foundation for creating the design. The aim of the WWWWWH method is to provide a structural framework for the design brief, to create clarity and focus, to understand the contextual relevance, to determine stakeholders, and to define the design goal.

What?

The goal is to design the future roles of human operators in scenarios where the autonomous bus system requires human intervention during the boarding and deboarding procedure at bus gates in airside operations. The concept should include future roles of human operators, their tasks, interactions, and communication with passengers, autonomous buses and other operators.

Who?

The stakeholders that are involved in this design are:

- **Human operators** are responsible for monitoring the autonomous system, on-site assistance, communication, and maintenance.
- **Gate agents** and **cabin crew** are responsible for the gate check-in and assist during passenger boarding in the airplane.
- **Passengers** play a central role in the usage of an autonomous bus system. The safety of passengers needs to be ensured at all times.
- **RSG** aims to be a disruptive innovator in autonomous airside operations. The autonomous bus systems needs to contribute to the strategically positioning of the company.

When?

The concept should determine the future roles of human operators, in scenarios where the autonomous bus system requires human intervention. The concept includes future roles for the upcoming 25 years to successfully reach the sustainability goals in 2050, determined by RSG.

Where?

The context of use is the airside at Schiphol Airport, where passengers will potentially be transported with autonomous buses from the terminal towards the airplane at remote bus gates.

Why?

As the testing phase with autonomous buses progresses at Schiphol Airport, there is a need to explore additional use cases beyond staff transport, such as passenger shuttle services from the terminal to remote stands at bus gates. Human operators continue to play essential roles in an autonomous bus but the role will change. Therefore, the human operators roles need to be determined before a future autonomous bus system can be implemented successfully.

How?

Storyboarding

Based on the literature study, context study, and in-depth expert interviews, key insights are combined and are used as a foundation to determine potential future scenarios where the autonomous bus system requires human intervention. Based on these scenarios, future roles are determined and further developed. The scenarios are visualized in different storyboards. The design of the storyboards is an iterative process, where multiple ideas are formed, roles are merged or separated, and redesigned. The use of storyboarding can help stakeholders understand the future context, system use, and interactions of the intended user group. In the evaluation phase of the design, storyboarding can be used to reflect on product form, values, and qualities used to start a discussion (Zijlstra et al., 2014).

Product concept evaluation

The storyboards are evaluated with different employees of the Innovation Hub within RSG, to assess the feasibility of the scenarios. Based on the feedback, iterations are made and the scenarios are further developed into a final design.

Prototyping

The final design is prototyped in the form of animation videos. The animations are used as a prompt for generating a rich discussion on the future human operator roles in an autonomous bus system and making the concept more tailored to the context of Schiphol Airport.

6. Towards future scenarios

This chapter describes the design phase of future human operator roles in different scenarios where the autonomous system requires human intervention. The ideation process of these scenarios and potential roles of human operators is presented in Section 6.1. The generated ideas are further developed into concepts (Section 6.2). The concepts are assessed with employees within the Innovation Hub of the organisation. Iterations are determined for the final concept in Section 6.3, and form the base for the final design in Chapter 7.

Aim: Generating ideas of potential future scenarios where human intervention is required during the boarding and deboarding process of an autonomous bus system in Autonomous Airside Operations.

RQ4: What are scenarios where the autonomous system's limitations require human intervention in an autonomous bus system and what are the human operator roles in these scenarios?

Source: photo courtesy of RSG (n.d)

6.1 Ideation

As proposed in Chapter 5, the design goal was to conceptualize the future roles of human operators in scenarios where human intervention is required during the boarding and deboarding process of an autonomous bus system in Autonomous Airside Operations. The aim of this chapter is to generate ideas for possible future scenarios, which will then be developed into concepts (Section 6.2) and ultimately into a speculative design prototype (Chapter 7).

To structure the ideation of these human roles in potential future scenarios, the process is divided into creating ideas for potential scenarios (Subsection 6.1.1) and further detailing the potential human operator roles (Subsection 6.1.2).

6.1.1 Potential scenarios

Approach

The outcomes of the context study identified the current responsibilities of human operators beyond driving-related tasks. Additionally, expert interviews provided insights into the additional responsibilities of future human operators in Autonomous Airside Operations. These factors were combined to create potential scenarios, including possible future roles.

Results

The ideation phase resulted in four potential future scenarios, each with corresponding future human operator roles. It is important to note that these designed scenarios are merely examples and other potential future scenarios are possible. Subsection 6.1.2 further elaborates on these potential roles.

Scenario 1: Face-to-face service providing

Figure 32 illustrates the synthesis of current and future human operator responsibilities. Currently, human operators act as social actors while providing service to passengers. In the future, their responsibilities may include enhancing passenger experience and managing passenger behavior. This combination has led to the potential future scenario of 'face-to-face service providing,' where the role of host or hostess is envisioned. The role description of the host or hostess will be presented in Subsection 6.1.2.

Even though face-to-face human interaction is not required in a fully autonomous bus system, offering face-to-face service for passengers can enhance the airport's service proposition. Currently, the bus driver and bus coordinator facilitate passenger interaction by answering questions, welcoming them, wishing them a safe flight, handling luggage for the aircraft hold, and providing wheelchairs and strollers after deboarding. Interviewed experts emphasized the importance of face-to-face service in building passenger trust, especially during the initial stages of using an autonomous bus.

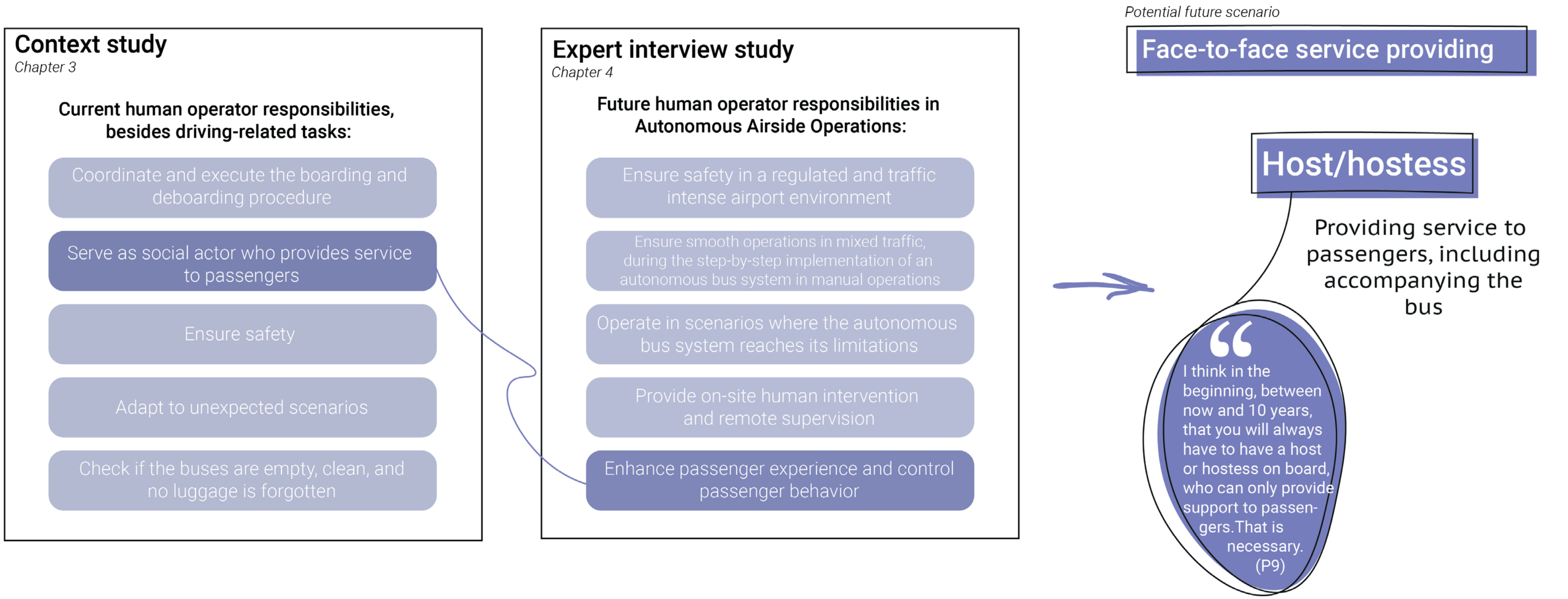


Figure 32: The synthesis of current and future human operator responsibilities, leading to the potential future scenario of 'face-to-face service providing' with the role of host or hostess

Scenario 2: Final check if the buses are empty, clean, and no luggage is forgotten

Figure 33 shows the synthesis of current and future human operator responsibilities. Currently, human operators are responsible for the final check after deboarding, to ensure that the buses are empty, clean, and no luggage is forgotten. In the future, these responsibilities might be partly taken over by the automated system with cameras and sensors. However, human operators remain essential in this scenario where the autonomous bus system reaches its limitations. This combination has led to the potential future scenario of 'the final check in the buses,' where the role of the fleet coordinator is envisioned. The role description of the fleet coordinator will be presented in Subsection 6.1.2.

After deboarding in current bus operations, the bus driver checks if all passengers have exited, ensures the bus is clean, and confirms no luggage has been left behind. In the future, this task will remain essential after every deboarding and must be performed either physically inside the bus or remotely using cameras and sensors. If the bus is dirty, the human operator must inform the cleaning staff. Additionally, if any luggage is forgotten, the driver must notify the passengers and arrange for the luggage to be returned to them.

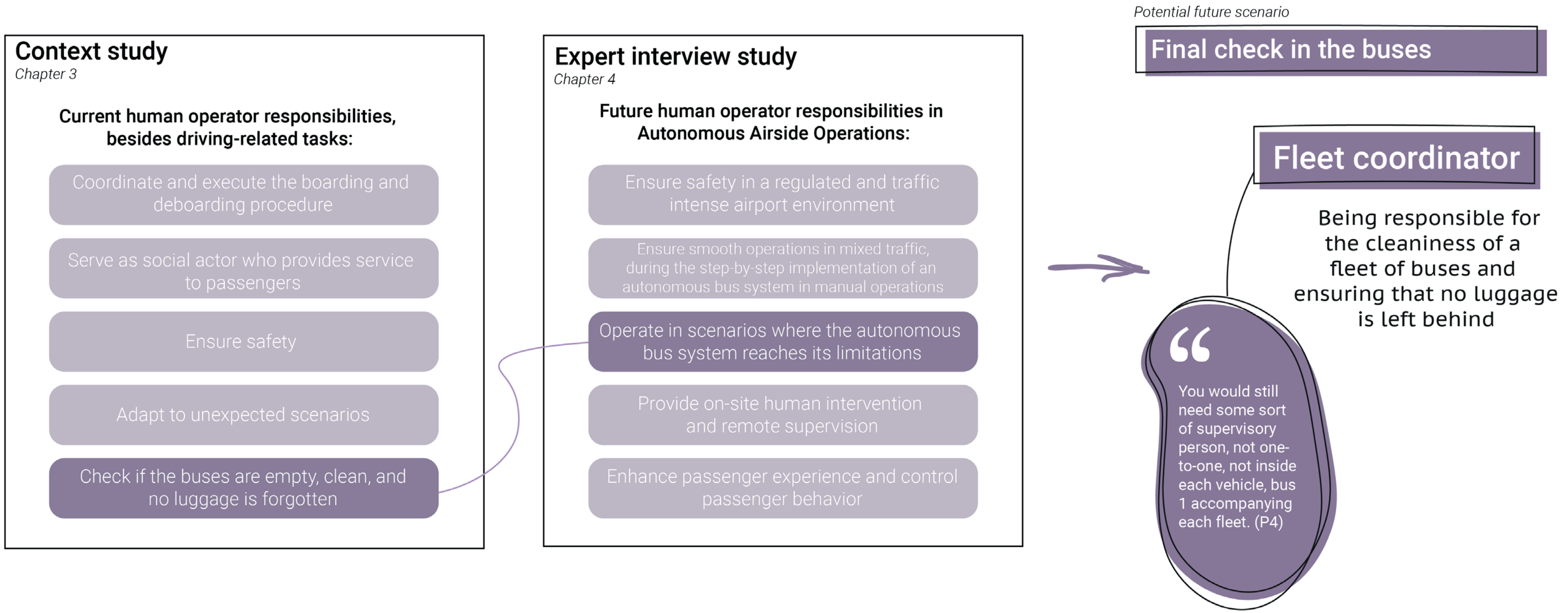


Figure 33: The synthesis of current and future human operator responsibilities, leading to the potential future scenario of 'the final check in the buses' with the role of fleet coordinator

Scenario 3: Boarding & deboarding assistance

Figure 34 illustrates the synthesis of current and future human operator responsibilities. Currently, human operators coordinate and execute the boarding and deboarding procedures for buses. In the future, their responsibilities will shift from driving-related tasks to focusing on enhancing passenger experience and managing passenger behavior. This combination has led to the potential future scenario of 'boarding & deboarding assistance,' envisioning the role of a boarding assistant. The role description of the boarding assistant will be detailed in Subsection 6.1.2.

In the current bus operations, bus drivers and coordinators handle boarding and deboarding assistance. In the future, this assistance will remain crucial and will need to be provided fully or partially by human operators, potentially aided by boarding instruction videos, cameras, and sensors. Based on observations from shadow shifts with bus drivers and coordinators, boarding and deboarding assistance involves overseeing the boarding process, counting passengers, welcoming them, helping with luggage inside the buses, opening and closing bus doors, and communicating with other human operators. New potential tasks include educating passengers about the new autonomous technology, ensuring their comfort, and assisting them with fastening their seat belts.

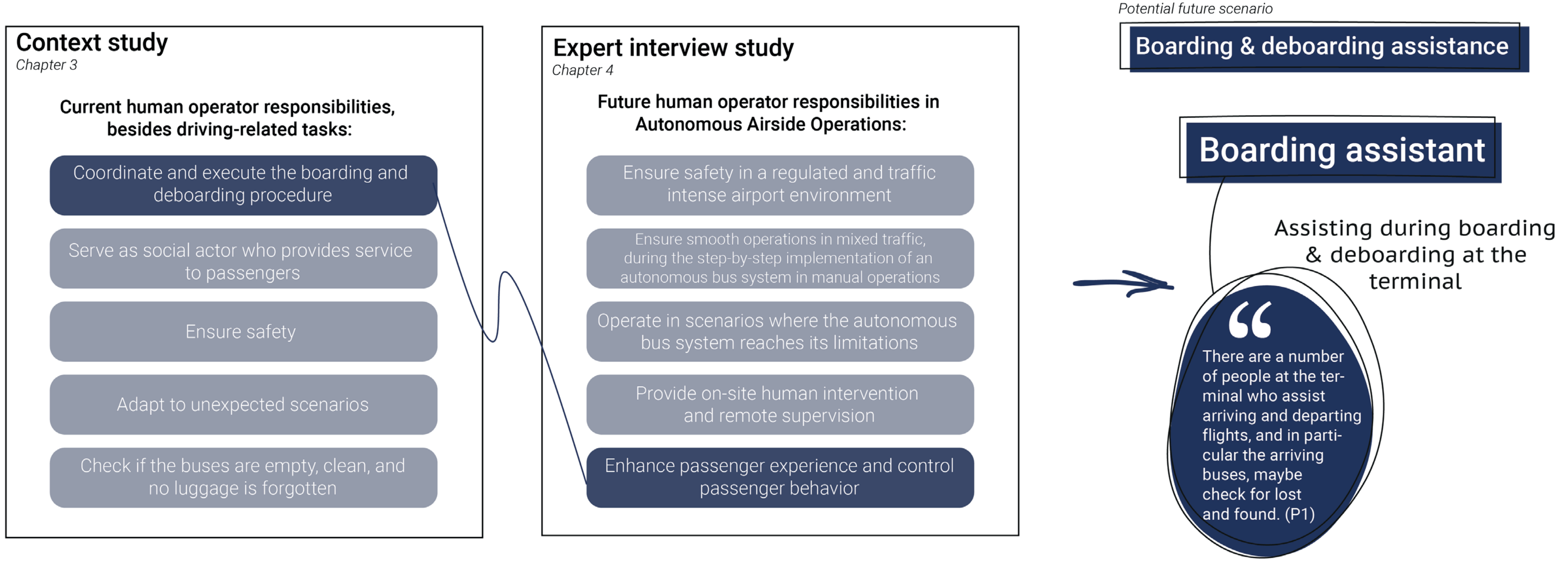


Figure 34: The synthesis of current and future human operator responsibilities, leading to the potential future scenario of 'boarding & deboarding assistance' with the role of boarding assistant

Scenario 4: Assistance in case of emergence

Figure 35 presents the synthesis of current and future human operator responsibilities. Currently, human operators are responsible for ensuring safety and adapting to unexpected scenarios. In the future, acknowledging the limitations of autonomous systems and the potential for emergencies, human operators will be tasked with ensuring safety in regulated, high-traffic airport environments and providing immediate on-site intervention during emergencies. This combination has led to the potential future scenario of 'assistance in case of an emergency,' envisioning the role of a rescuer. The role description of the rescuer will be detailed in Subsection 6.1.2.

In the current bus operations, the bus coordinator is responsible to assist in case of emergency, by physically going to the buses. Experts emphasize the need for immediate face-to-face intervention in an autonomous bus system to reassure passengers, resolve minor malfunctions, escort passengers to a safe area, and wait for a backup bus.

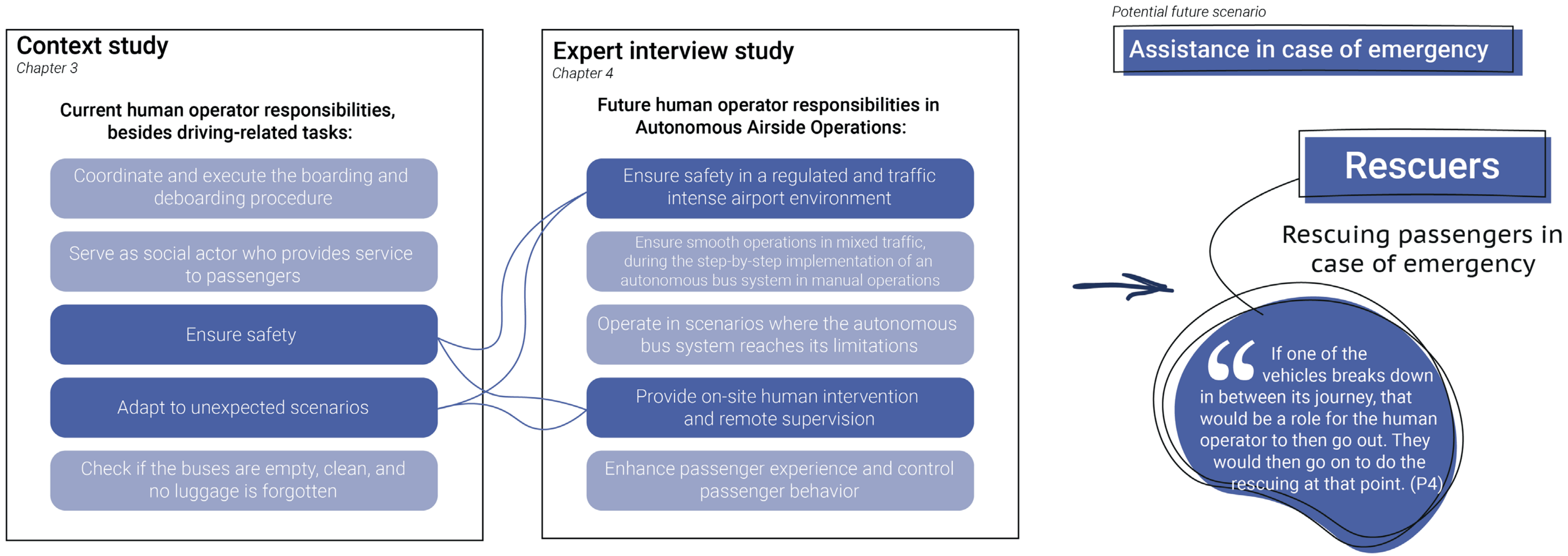


Figure 35: The synthesis of current and future human operator responsibilities, leading to the potential future scenario of 'Assistance in case of an emergency with the role of rescuer

6.1.2 Potential roles

Based on the expert interviews, in combination with the context study insights, the conclusion can be drawn that the human operator has a variety of remaining tasks besides driving. A list of human operator tasks identified during the context study and expert interviews is compiled and presented in Appendix C. Based on a combination of identified tasks and expert insights, potential future roles are determined. Figure 36 supports the ideation process of potential roles, by presenting citations from experts during interviews that relate to potential roles. The following paragraphs provide a description of the potential roles.

Supervisor

The supervisors are responsible for monitoring the process from a remote location, by checking cameras and assessing alert-based notifications. He or she is in close contact with other human operators that are working in the system. The tasks of the supervisor differ, depending on whether an operator is still physically present on the bus or not. If there is no human operator involved, the supervisor also functions as the contact person for passengers on the bus.

Safety driver

The safety drivers are required in a Level of Automation (LoA) 3 vehicle and have the responsibility to ensure supervision on board. A safety driver is present in the bus and covers a lot of human operator tasks, including assisting during boarding and deboarding, making sure passengers put on their seat belts, solving small malfunctions, manually taking over the bus when necessary, and keeping the bus clean. Additionally, a safety driver functions as a social actor for passengers, who explains how the technology works, who makes passengers feel at ease, and who answers questions.

Host/hostess

The host or hostess is a potential role who accompanies the bus, even if a safety driver is not required anymore, to provide service to passengers, make passengers feel at ease, and answer questions from passengers. Experts mentioned during the in-depth interviews, the importance of still having real human interaction in an autonomous world, especially in case of emergency. The host or hostess serves in this service-providing role.

Fleet coordinator

Instead of having one host of hostess accompanying every bus, the possibility also arises to create a role who is responsible for overseeing the whole fleet. The fleet coordinator has the same tasks as the host of hostess.

Boarding assistant

The host or hostess and the fleet coordinator are both roles that accompany the buses. However, there is also the possibility to have human operators at fixed positions during the boarding procedure, who do not accompany the bus. The main responsibility of the boarding assistant is to ensure a safe boarding and deboarding procedure.

Remote driver

Remote drivers are human operators that can manually take over the buses from a remote location. In case of an error, for example when there is an obstacle on the road, the remote drivers can drive around that obstacle with a joystick or remote steering wheel. After the remote drivers drive the bus to a safe location, the bus can continue driving autonomously.

Rescuer

When no human operator accompanies the buses, human operators remain essential in anticipating on unexpected scenarios in case of emergency. Safety is the main priority on the airside. Therefore, in case of emergency, the rescuers immediately drive towards the bus, prevent passengers from walking away, and solve small malfunctions. After resolving, the bus can continue its route towards the airplane.

Maintenance and cleaning operators

Currently, RSG already has maintenance engineers and cleaning operators and these will remain essential in an autonomous bus system. The role of the cleaning operator will not be impacted radically. When an autonomous bus becomes dirty, the bus is able to drive autonomously towards the depot, where the cleaning staff can clean the bus. However, the role of the maintenance engineers will change. In the future, maintenance engineers will, besides physical maintenance, also become experts in autonomous technology. This requires new skills, such as software development and conducting updates.

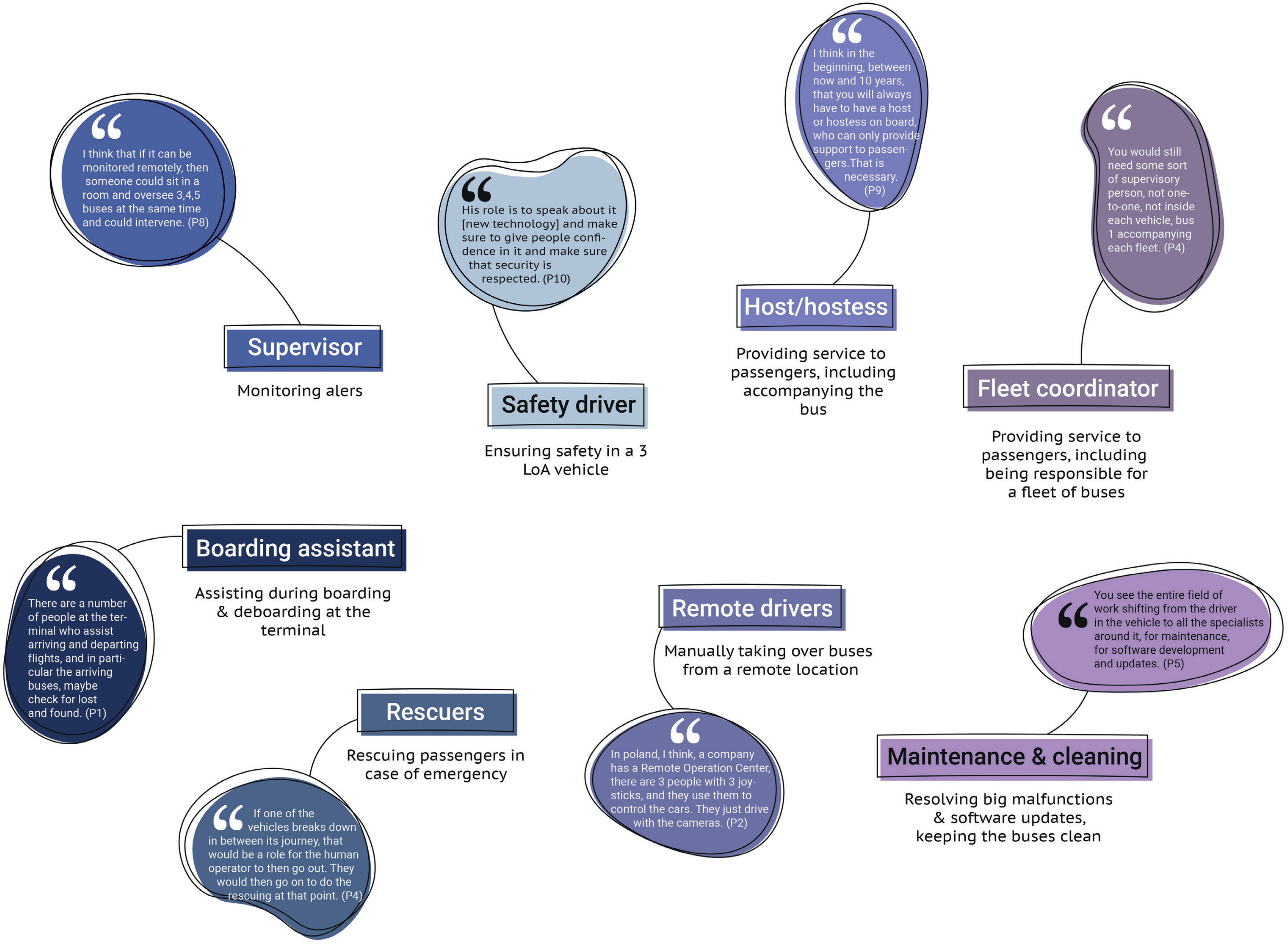


Figure 36: Overview of participant quotes from expert interviews, leading to the ideation of potential roles.

6.2 Concepts

In Section 6.1, potential future scenarios where the autonomous system requires human intervention and human operator roles are identified. In this section, the 4 potential scenarios are further developed in the following concepts.

6.2.1 Concept 1: Face-to-face service providing

Involved roles

- Host/ hostess
- Supervisor
- Maintenance engineer
- Cleaning staff

Concept description

During the initial stage of an autonomous bus system implementation, a safety driver is mandatory to provide on-board supervision. As the autonomous bus system evolves, the need for a safety driver will be phased out. Currently, human operators not only drive but also provide face-to-face service to passengers. By eliminating the driving task, the focus can shift entirely to service provision by introducing a host or hostess on board to attend to passenger needs.

The host or hostess works closely with supervisors, engineers, and cleaning staff, taking on responsibilities such as welcoming passengers, assisting with luggage, and ensuring passenger safety and comfort. The primary focus for the host or hostess is face-to-face interaction and service provision.

As the autonomous buses depart and commute toward the airplane, the host or hostess remains on board, addressing passenger inquiries, maintaining safety standards, and providing assistance as needed. The host or hostess is present to have nice conversations with passengers and answer questions about the autonomous technology or other travel-related questions. In case of an error, the supervisor receives an alert and communicates with the host or hostess. The host or hostess assesses the situation, resolves minor malfunctions if possible, communicates with the supervisor, and continues the route.

After arriving at the airplane, the host or hostess assists with deboarding and wishes passengers a safe flight. When passengers have oversized luggage, the host or hostess assists them by bringing the luggage to the cargo hold. Afterward, the host or hostess rejoins the bus and starts with the next task.

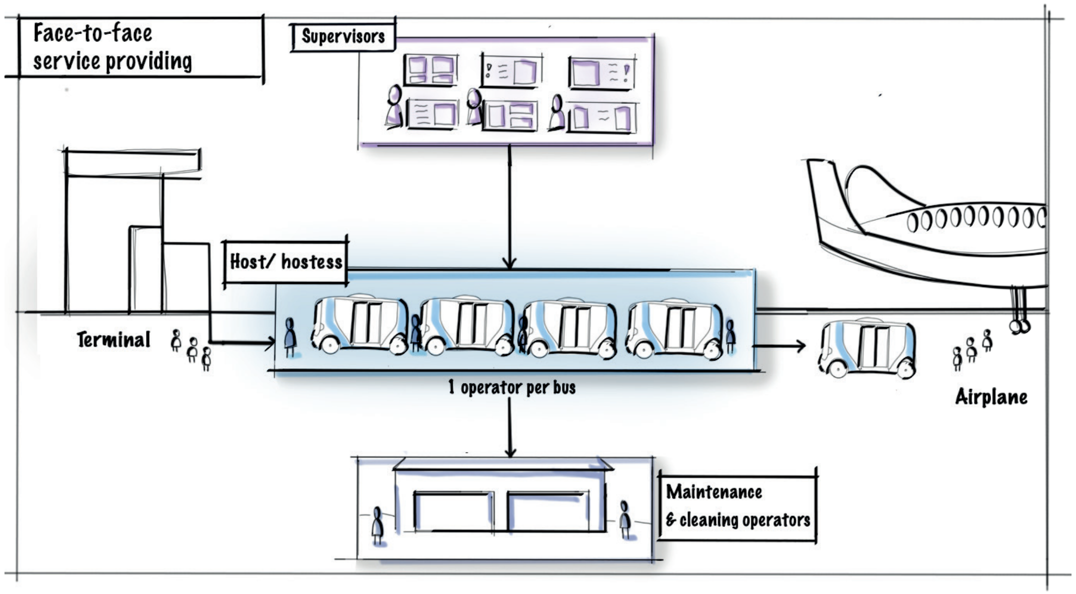


Figure 37: System design for the host scenario

The system design for the host or hostess scenario is illustrated in Figure 37. Additionally, Figure 38 presents a storyboard that elaborates on the tasks and interactions involved in the role of the host or hostess.

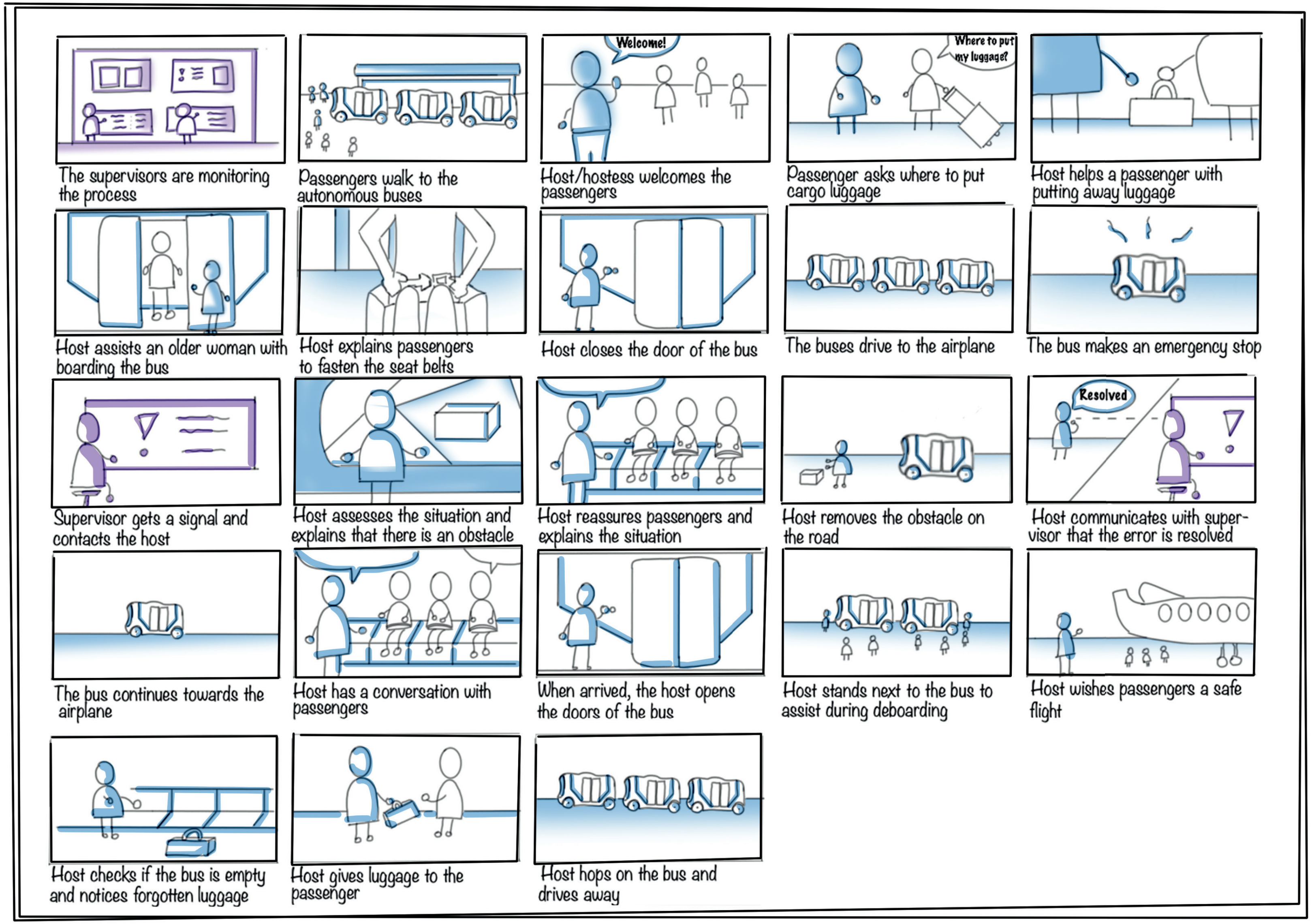


Figure 38: Storyboard about the roles and interactions of the host/hostess

6.2.2 Concept 2: Final check if the bus is empty, clean, and no luggage is forgotten

Involved roles

- Fleet coordinator
- Supervisor
- Maintenance engineer
- Cleaning staff

Concept description

In future operations, ensuring that buses are empty, clean, and free of forgotten luggage will remain crucial and must be managed either fully or partially by human operators, utilizing cameras and sensors as necessary.

This requires the creation of a role dedicated to overseeing the fleet of buses. The fleet coordinator will assume responsibilities similar to those of a host or hostess, but instead of having one human operator per bus, a single coordinator will oversee the entire fleet.

Upon arriving at the airplane, the fleet coordinator will exit the bus, coordinate deboarding, and wish passengers a safe flight. After all passengers have deboarded, the fleet coordinator will inspect the buses to ensure they are empty, clean, and free of any forgotten luggage. If the bus is dirty, the fleet coordinator will communicate with the supervisor and send the bus to the maintenance depot for cleaning. The supervisor will dispatch a backup bus for the next procedure. If luggage is forgotten on the bus, the fleet coordinator will deliver it to the cabin crew for departing flights or bring it to Lost & Found for arriving flights. Once the checks are complete, the fleet coordinator will rejoin the fleet and proceed to the next task.

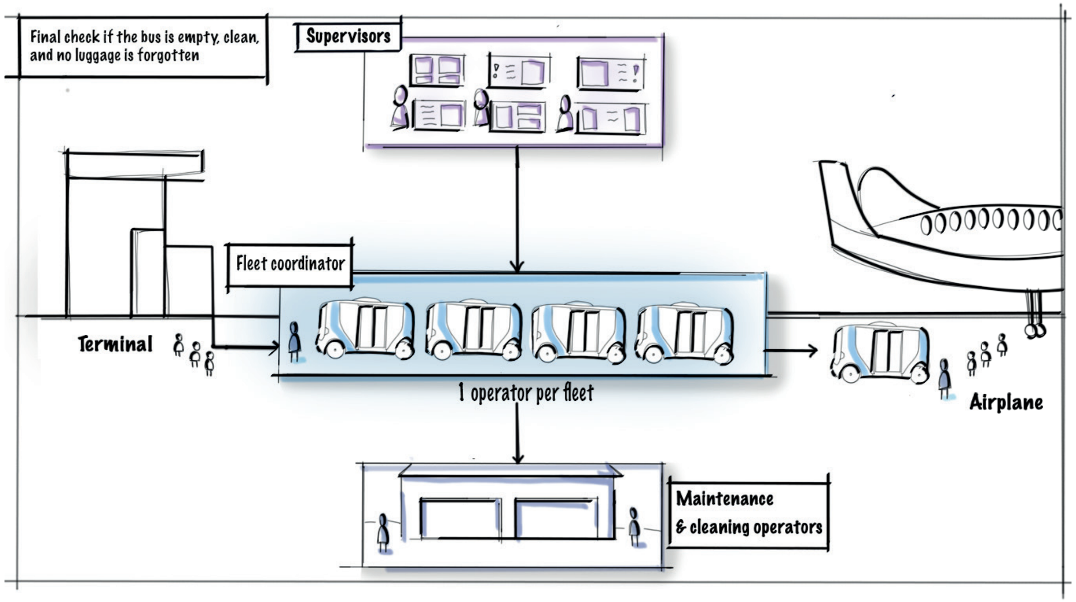


Figure 39: System design for the fleet coordinator scenario

The system design for the fleet coordinator scenario is illustrated in Figure 39. Additionally, Figure 40 presents a storyboard that elaborates on the tasks and interactions involved in the role of the fleet coordinator.

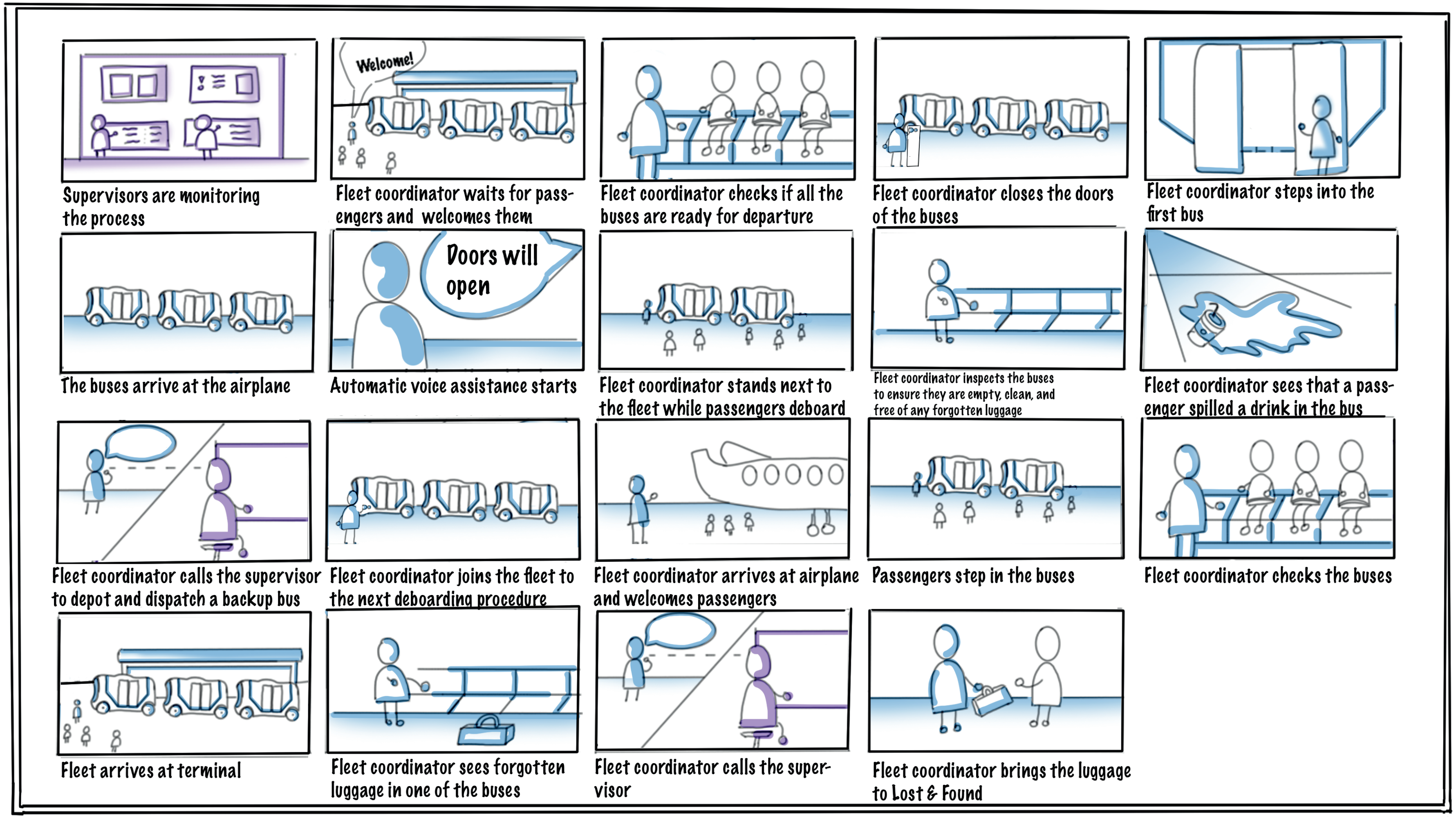


Figure 40: Storyboard about the roles and interactions of the fleet coordinator

6.2.3 Concept 3: Boarding & deboarding assistance

Involved roles

- Boarding assistant
- Supervisor
- Cabin crew
- Maintenance engineer
- Cleaning staff

Concept description

If there is eventually no need for on-board service, the host, hostess, or fleet coordinator might be removed from the bus or fleet. However, human operators remain crucial for ensuring a safe and comfortable boarding and deboarding process. In this case, boarding assistants will be stationed at fixed positions outside the terminal.

Boarding assistants will manage the boarding process by welcoming passengers, assisting with luggage inside the buses, and helping passengers fasten their seat belts. Once all passengers are seated and the buses are checked, the boarding assistants will exit the buses and close the doors. During the commute, remote supervision will monitor the system and passenger behavior through interior cameras and sensors, increasing the responsibilities of the supervisors.

Upon arrival at the airplane, automatic voice instructions will guide passengers during deboarding, with assistance from the cabin crew. Once all passengers have exited the buses, the cabin crew will close the doors, allowing the bus to proceed with its next task. In this scenario, the cabin crew will take on additional tasks.

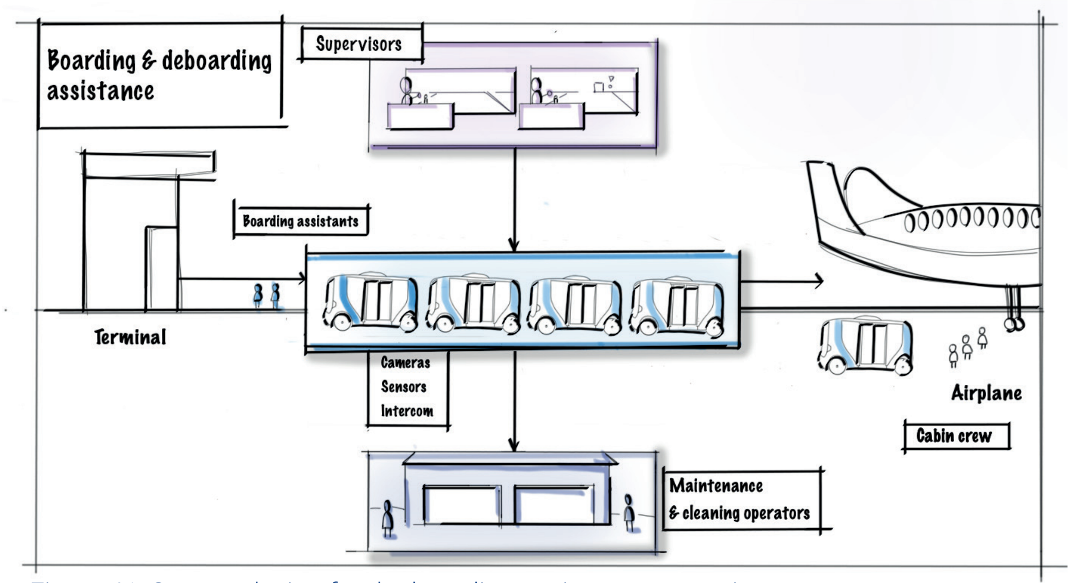


Figure 41: System design for the boarding assistance scenario

The system design for the boarding assistance scenario is illustrated in Figure 41. Additionally, Figure 42 presents a storyboard that elaborates on the tasks and interactions involved in the role of the boarding assistant.

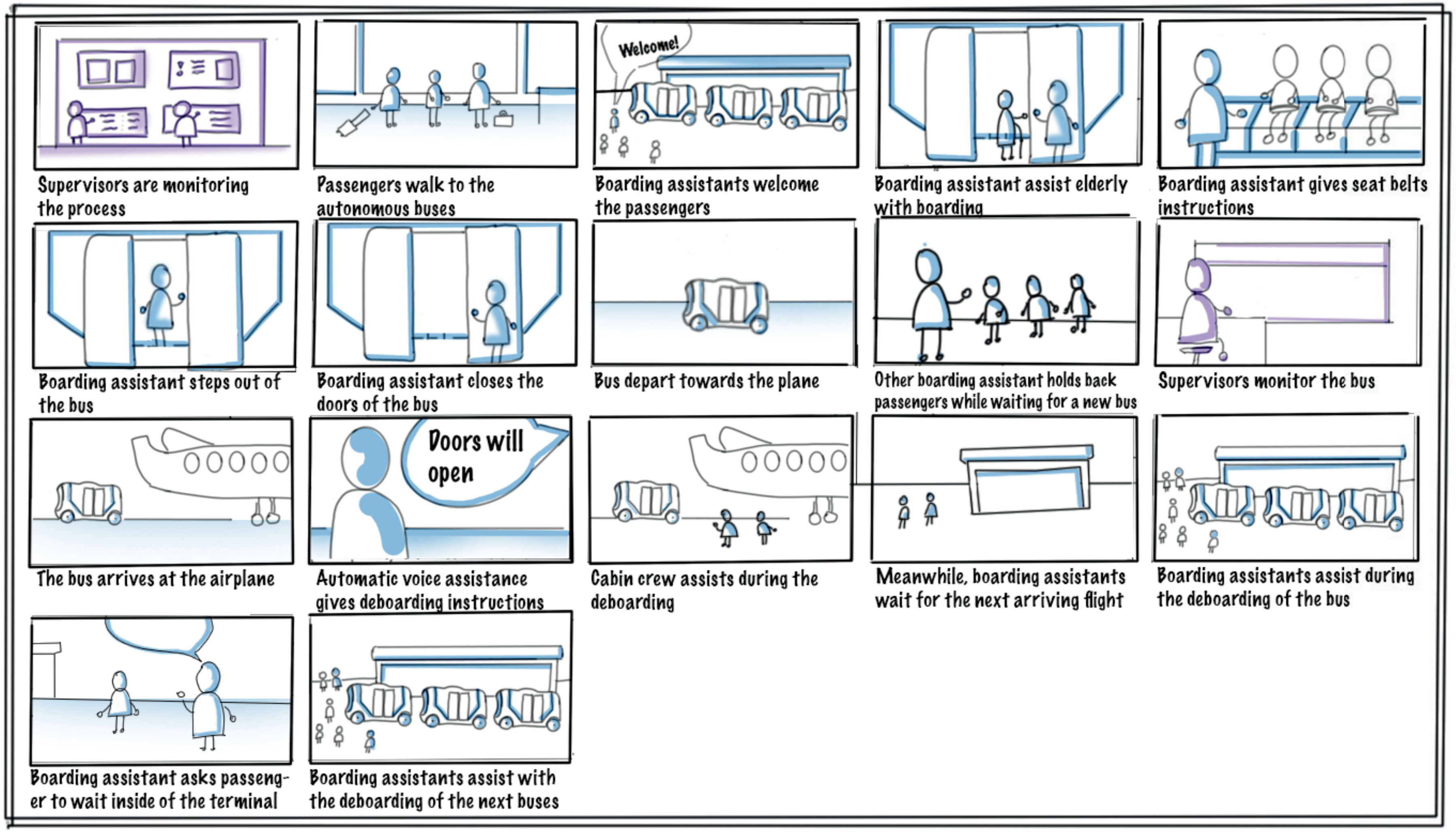


Figure 42: Storyboard about the roles and interactions of the boarding assistance

6.2.4 Concept 4: Assistance in case of emergency

Involved roles

- Rescuer
- Supervisor
- Cabin crew
- Maintenance engineers
- Cleaning staff

Concept description

In this scenario, no operators accompany the buses, and no boarding assistants assist during boarding, only supervisors monitor the system from a control room using cameras and sensors. In such a scenario, without direct interaction with human operators, human operators remain crucial for safety during emergencies. Expert interviews emphasized the need for direct communication with human operators in such situations, leading to the creation of the rescuer role.

After passengers walked to the autonomous buses, boarded, and fastened their seat belts, the buses departed. Sensors monitor the bus interior, detecting if passengers haven't fastened their seat belts or if luggage is too close to the door. An automatic voice assistant helps manage passenger behavior.

If an emergency occurs during transit, remote supervisors receive alerts and immediately coordinate with rescuers, who attend the scene with high priority. Passengers are reassured via an automated voice assistant that rescuers are on their way. Upon arrival, rescuers provide support and escort passengers to a designated safe area. The rescuers assess the situation and communicate this with the supervisors. Supervisors dispatch a backup bus if needed, while rescuers address minor malfunctions on-site. If the malfunction cannot be resolved, the bus proceeds to the maintenance depot, and passengers continue their journey on the backup bus.

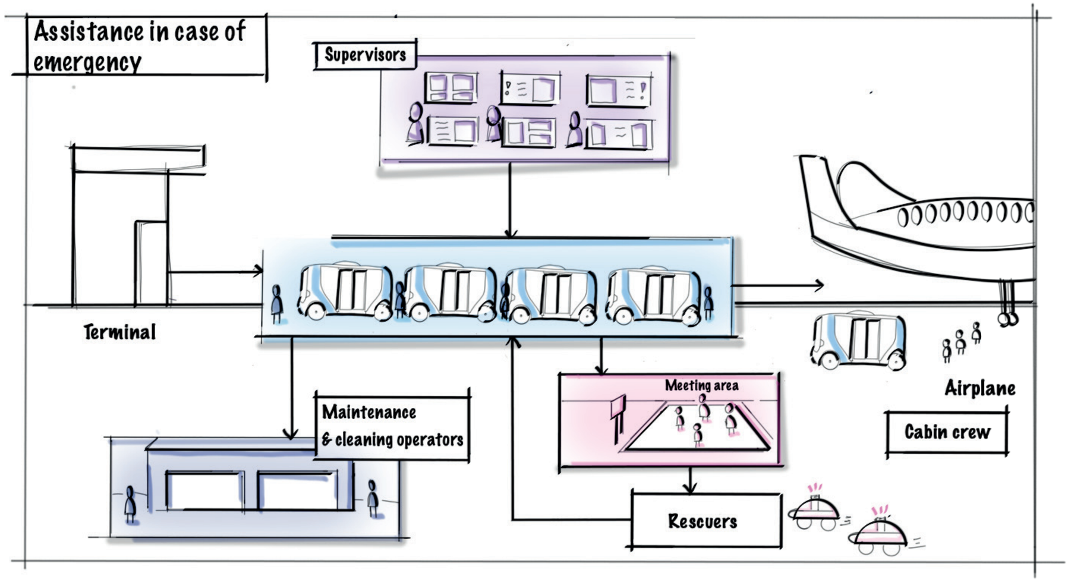


Figure 43: System design for the rescuer scenario

Upon arrival, passengers receive deboarding instructions from the automated voice assistant on the bus. The cabin crew oversees airplane boarding. Meanwhile, interior sensors check for cleanliness and forgotten items. If necessary, supervisors arrange for cleaning at the depot before the bus resumes its operations.

The system design for the rescuer scenario is illustrated in Figure 43. Additionally, Figure 44 presents a storyboard that elaborates on the tasks and interactions involved in the role of the rescuer.

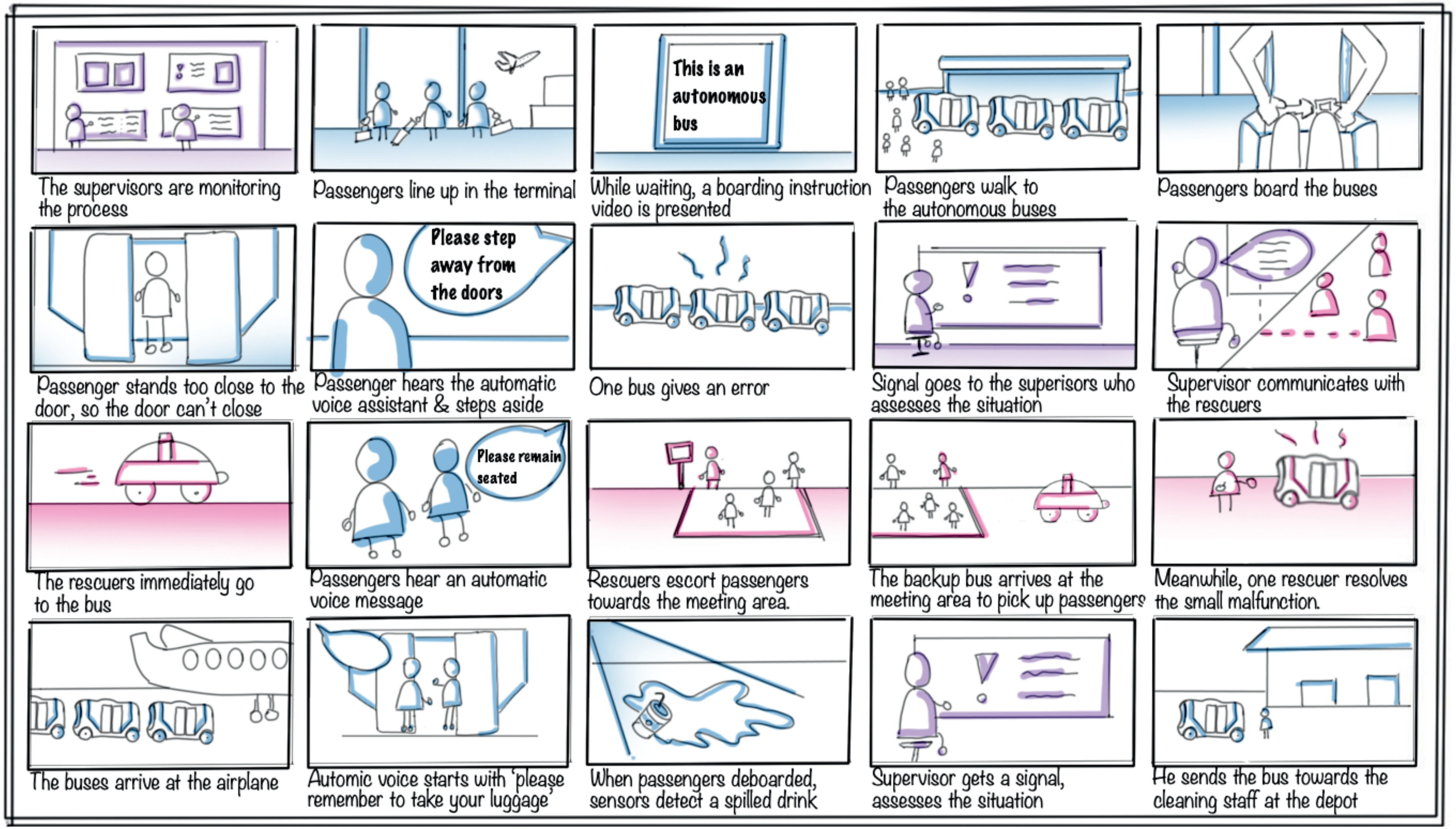


Figure 44: Storyboard about the roles and interactions of the rescuer

6.3 Iterations

The concepts of the potential scenarios were presented to and discussed with various innovators within the organization of RSG (i.e., 1 innovation lead of AAO, 1 innovation lead of the autonomous bus project, 1 in-house consultant working on the autonomous bus project) and with the supervisory team during unstructured conversations. Based on these conversations, recommendations for the iteration of the final design were determined. The feedback is clustered into 6 key areas:

Combining the role of host and fleet coordinator
Both the host and fleet coordinator roles involve accompanying the buses or a fleet of buses. It was suggested that the host could take over the tasks of the fleet coordinator, such as checking if the buses were clean, empty, and free of forgotten luggage.

Linking the current situation with potential future scenarios
First, employees from the Innovation Hub recommended introducing a first phase where autonomous buses are integrated into the current manual bus operations, including the existing roles (i.e., the bus director, the bus coordinator, and the bus driver) along with autonomous buses operated by a safety driver. This phase aims to test the feasibility of the automated system and gradually familiarize passengers with autonomous buses. Additionally, it was emphasized that passenger acceptance is crucial:

"You can't force passengers to take the autonomous bus at the initial stage." - Innovator at RSG

Innovators from RSG highlighted that, during this first phase, the capacity of the buses is a critical factor for the execution of autonomous operations alongside manual operations. Thus, the strategy for deploying autonomous buses needs to be determined (e.g., using an autonomous bus as the last one in the fleet or employing an entire autonomous fleet for smaller airplanes). The preferences of the bus director should be consulted for this implication. Lastly, it is important to highlight the distinction between the current bus driver and the safety driver.

Determining the relationship between the different scenarios
Each scenario seems to differ in dimensions, which are: increased autonomy, de responsibility of the driving task of the driver, passenger trust, and passenger interaction. Determine how different scenarios behave in relation to each other, based on these dimensions.

Reducing the focus on emergencies
Innovators from RSG emphasized that Schiphol Airport would only implement an autonomous bus system for passenger transport if the system operates without errors. Therefore, the final concept should reduce the emphasis on emergencies. Instead, focus on enhancing the passenger experience and demonstrate how the different human operator roles could enhance the airport's service proposition.

Adding passenger education before boarding
One employee from the Innovation Hub team mentioned that the boarding assistants could be stationed inside the terminal to guide passengers to the buses. Additionally, she highlighted that it is crucial to educate passengers about autonomous bus operations beforehand. Boarding instructions can be sent to passengers in advance, similar to the current security check instructions.

Changing the design of the buses
It was noted that people assumed the current Ohmio buses, which do not have sufficient capacity, would be used. Therefore, the design of the buses needs to be revised to ensure they meet the required capacity standards.

These recommendations are integrated into the final design, presented in Chapter 7.

7. Final design

This chapter presents the final design for the future roles of human operators in an autonomous bus system in Autonomous Airside Operations, in scenarios where the autonomous bus system requires human intervention. Derived from the insights of the literature study, expert interviews, and insights from shadowing the current bus operations, different scenarios were developed in Chapter 6. Feedback from various innovators within the RSG innovation team and the supervisory team shaped the final design presented in this Chapter. The final design consists of animation videos and includes 4 different scenarios where human operators remain essential in an autonomous bus system in airside operations: (1) Addition to manual operations; (2) On-board service providing; (3) Boarding & deboarding assistance; and (4) Assistance in case of emergency. Section 7.1 provides dimensions on which the different scenarios a built upon. Section 7.2 gives a description of the final scenarios, while Section 7.3 outlines the job descriptions for future human operator roles required for autonomous bus operations. Section 7.4 presents the final storyboards for the animation videos, which function as speculative design artifacts.

Aim: To create a prototype, serving as a speculative design artifact, of future human operator roles in potential future scenarios where human operator remain essential.

RQ4: What are scenarios where the autonomous system's limitations require human intervention in an autonomous bus system and what are the human operator roles in these scenarios?

Source: photo courtesy of RSG (n.d)

7.1 Determining the dimensions of the concept

The final concept consists of four scenarios where human operators remain essential in an autonomous bus system in Autonomous Airside Operations: (1) Addition to manual operations; (2) On-board service providing; (3) Boarding & deboarding assistance; and (4) Assistance in case of an emergency.

To understand the relationships between these scenarios, a matrix (Figure 45) is created, consisting of two dimensions: the level of direct human operator interaction (LoI) and the expected Level of Automation (LoA). With the level of direct human operator interaction, we refer to how much face-to-face interaction passengers have with a human operator in the scenario. The expected LoA refers to the evolving technological capabilities of the automated system, based on insights from the expert interviews. Each scenario is assessed on LoA and LoI, as presented in Figure 46. In Figure 47, a visualization of the matrix is presented, where the different scenarios are placed in the matrix to show how they relate to each other.

Based on the expert interviews, the following assumptions are made about the level of automation:

- **Low LoA**: With exterior cameras, the bus system is capable of detecting obstacles on the road.
- **Medium LoA**: Remote supervisors are able to send a backup bus on-site and send the broken bus towards the maintenance depot.
- **High LoA**: With sensors and interior cameras, the bus system is capable of detecting if passengers are standing too close to the door, and if de bus is empty, and clean, and no luggage is forgotten after the deboarding procedure.

Level of Automation	Low interaction (Remote Supervision)	Medium interaction (Occasional assistance)	High interaction (Constant on-board presence)
Low (Manual)	Autonomous bus as addition to manual operations with remote supervision	Autonomous bus as addition to manual operations with assistive operators at fixed positions	Autonomous bus as addition to manual operations with on-board conductor to manually take-over
Medium	Autonomous driving with remote supervision who could interrupt	Autonomous driving with assistive operators at fixed positions who could interrupt	Autonomous driving with on-board service operator who could interrupt
High (Full automation)	Fully autonomous with remote monitoring and assistance in case of emergency	Fully autonomous with assistive operators at fixed positions outside of the buses	Fully autonomous with on-board service operator

Figure 45: Custom matrix for an autonomous bus system, presenting the Level of Automation (LoA) and the Level of direct human operator Interaction (LoI)

In this created matrix, the LoA is determined based on Levels of Driving Automation from the Society of Automotive Engineers J3016 (SAE, 2021), presented in subsection 2.3.4. In regards to the LoI, in this matrix:

- **Low Interaction** might involve remote supervision with minimal direct passenger interaction.
- **Medium Interaction** could include scenarios where an operator occasionally assists passengers directly at fixed positions during the boarding and deboarding procedure, outside of the bus.
- **High Interaction** would involve scenarios with a constant human presence on board for high levels of passenger interaction.

An overview of future human roles in an autonomous bus system in airside operations is presented in Figure 48. Each scenario will be further explained in this Chapter.

Scenario	LoA	LoI
Addition to manual operations	Low	High
On-board service providing	Medium	High
Boarding & deboarding assistance	High	Medium
Assistance in case of emergency	High	Low

Figure 46: Matrix that indicate the Level of Automation (LoA) and the Level of Interaction (LoI) of each scenario

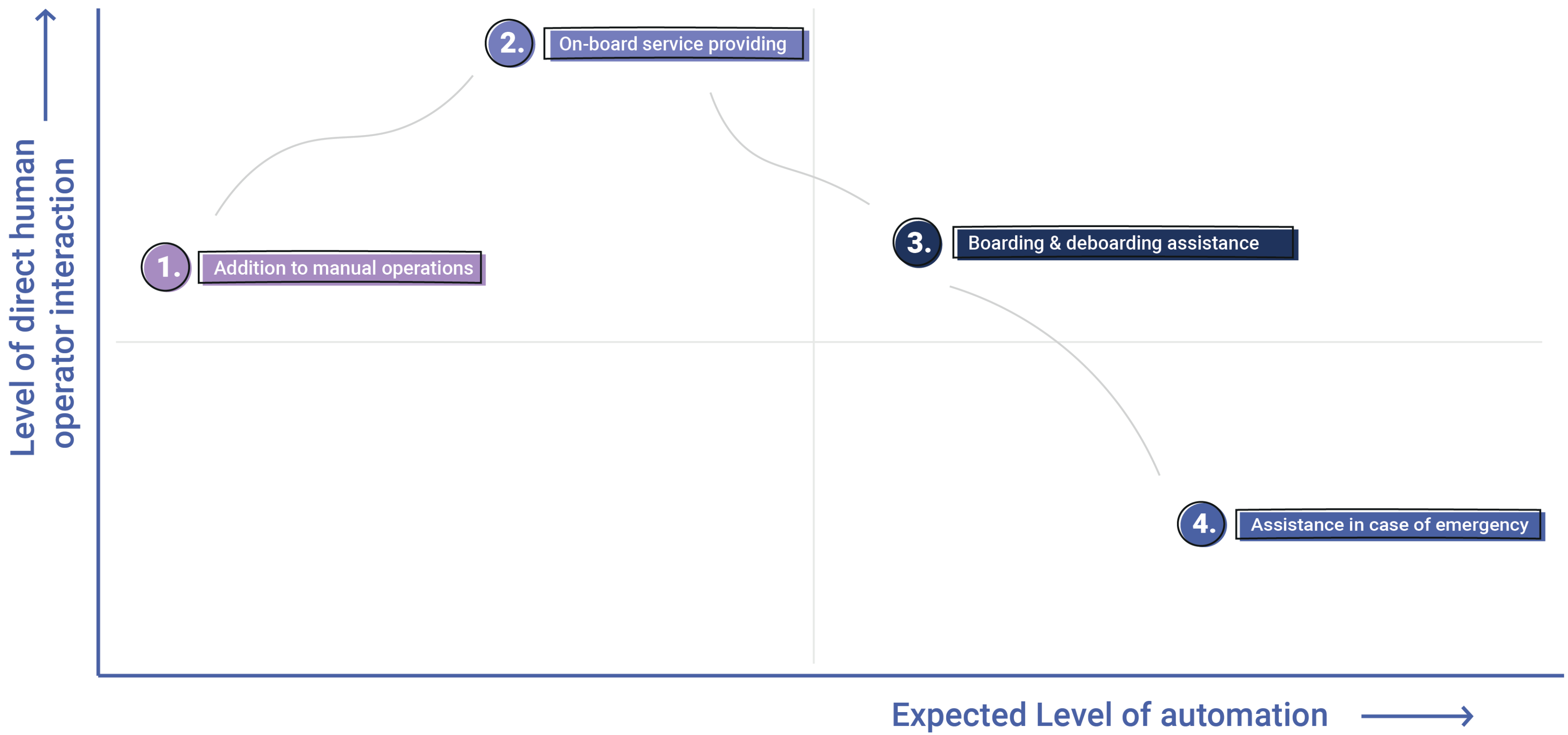
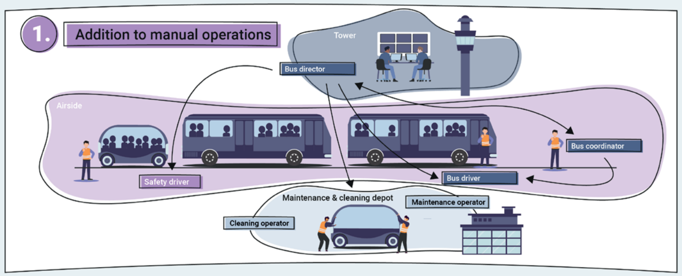


Figure 47: Visualisation of the matrix that shows how the different scenarios relate to eachother. The horizontal ax shows the expected Level of Automation (LoA) and the vertical ax shows the level of direct human operator interaction from a passenger perspective.

The future roles of human operators in an autonomous bus system in Autonomous Airside Operations

Scenario



New roles

Safety driver

Job description

A safety driver is responsible for monitoring the vehicle's operations, ensuring passenger safety, and intervening when necessary to prevent accidents or address unexpected situations.

Duties and responsibilities

- **Ensure safety on board**
- **Communication with passengers**
- **Manual takeover**
- **Let passengers put on seat belts**
- **Make passengers feel at ease**
- **Educate passengers**
- **Answer questions from passengers**
- Give boarding instructions
- Keep the buses clean
- Prevent passengers from moving freely
- Control passenger behavior
- Assess the situation
- Open & close the doors of the buses
- Check forgotten luggage
- Assist passengers with luggage
- Communicate with other human operators
- Check if the buses are empty
- Resolve small malfunctions
- Check if the buses are clean
- Assist during boarding and deboarding

Requirements

- Welcoming towards passengers
- Communication skills for passenger interaction and coordination with other human operators
- Open to learn new things
- Driver's license
- Ability to remain focused in unexpected scenarios
- Comfortable with autonomous technology with basic understanding of the system
- Capable of manually operating vehicle controls if needed
- Proficiency in both Dutch and English languages

Existing roles

Bus director

Additional duties and responsibilities:

- Monitor autonomous bus alerts
- Communication with safety driver
- Send autonomous buses with big malfunction to depot
- Send autonomous back up bus

Cleaning & maintenance operator

Additional duties and responsibilities:

- Conduct software updates
- Daily bus system check
- Keep autonomous buses clean
- Resolve big malfunctions

Bus coordinator

Additional duties and responsibilities:

- Assist the safety driver in case of emergency
- Assist during boarding and deboarding of the autonomous buses

Bus driver

Additional duties and responsibilities:

- Anticipation on mixed traffic
- Communication with safety driver

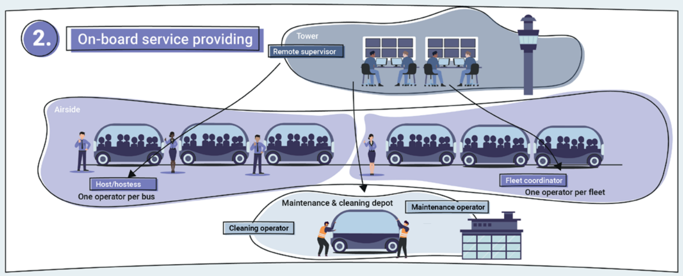
Expected LoA

Automated system

Tasks taken over by the autonomated system:

Sense	Plan	Act
		• Driving

Based on the model from Beer et al. (2014).



Host/hostess or fleet coordinator

Job description

A host/hostess or fleet coordinator accompanies the bus or a fleet to provide service towards passengers, answers questions from passengers, helps with luggage, educates passengers, and makes them feel at ease.

Duties and responsibilities

- **Make passengers feel at ease**
- **Communication with passengers**
- **Assist passengers with luggage**
- **Educate passengers**
- **Answer questions from passengers**
- **Intervene with the autonomous system**
- Resolve small malfunctions
- Let passengers put on seat belts
- Check if the buses are clean
- Assist during boarding and deboarding
- Give boarding instructions
- Keep the buses clean
- Prevent passengers from moving freely
- Control passenger behavior
- Assess the situation
- Open & close the doors of the buses
- Check forgotten luggage
- Check if the buses are empty
- Ensure safety on board

Requirements

- Strong communication skills for passenger interaction and coordination with other human operators
- Welcoming towards passengers
- Representative appearance
- Proficiency in both Dutch and English languages
- Comfortable with autonomous technology with basic understanding of the system
- Capable of manually operating vehicle controls if needed
- Driver's license

Remote supervisor

Job description

A remote supervisor is responsible for monitoring the autonomous bus system from a remote location, by checking the cameras and assessing alert-based notifications. When a malfunctions occurs which is unable to be resolved by the system itself, the supervisor assesses the situation and provide solutions while upholding safety standards.

Duties and responsibilities

- **Monitor alerts**
- **Assess the situation**
- **Watch the cameras**
- **Communication with passengers**
- Control passenger behavior
- Communication with other human operators

Requirements

- Advanced knowledge of autonomous systems and their operation
- Proficiency in remote monitoring and management systems
- Ability to remain focused and attentive during extended periods of remote operation
- Excellent communication skills for coordinating with on-site teams
- Strong analytical skills to interpret data
- Ability to make quick and accurate decisions in response to emergent situations or technical issues
- Technical aptitude to resolve issues remotely
- Knowledge of safety protocols and regulations governing autonomous vehicle operations
- Proficiency in both Dutch and English languages

Cleaning & maintenance operator

No additional tasks & requirements based on the current role.

Automated system

Tasks taken over by the autonomated system:

Sense	Plan	Act
	• Update bus scheduling	• Driving

Based on the model from Beer et al. (2014).

→ Interaction between human operators

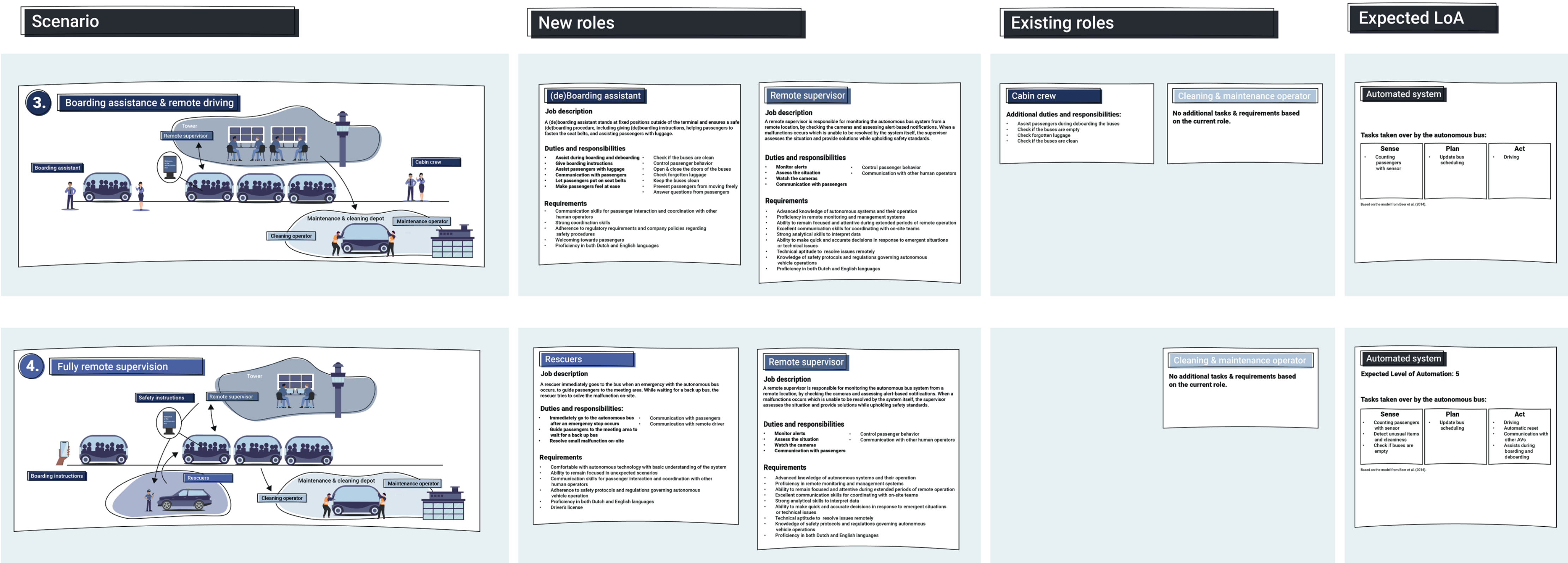


Figure 48: Overview of the final design: left to right - (a) scenarios for the autonomous bus operations (i.e., addition to manual operation, on board service providing, boarding & deboarding assistance, and assistance in case of emergency) , (b) role description of the new roles per scenarios (c) role description of existing roles per scenario, (d) expected Level of Automation per scenario.

7.2 Scenario descriptions

7.2.1 Scenario 1: Addition to manual operations

Phase one introduces autonomous buses alongside the existing manual operations. As flights arrive and depart, traditional buses continue their service, with autonomous buses used as an addition to manual operations. Assuming that the capacity of the autonomous buses is lower than the manual buses in the initial stages, autonomous buses will operate as the final shuttle bus in the fleet. Different innovators from RSG highlighted the importance of allowing passengers to choose between manual and autonomous buses during this phase. Gradually, the manual buses will be phased out and more autonomous buses will be integrated into the fleet.

Current human roles remain fundamental during this phase. The bus driver will continue to operate manual buses, the bus coordinator will assist on-site operations, and the bus director will schedule and monitor both manual and autonomous buses. Autonomous buses will be operated by a safety driver. During commutes, the safety driver will be responsible for monitoring the vehicle's operations, ensuring passenger safety, communicating with and educating passengers about the new technology, and intervening when necessary by manually taking over the bus to prevent accidents or address unexpected situations.

The bus will be able to detect obstacles on the ground with sensors and cameras. In case an obstacle is detected, the safety driver will receive an alert, assess the situation, communicate with the bus director and resolve the malfunction by manually taking over the bus with a joystick. After that, the operator explains the situation to the passengers and continues the journey.

Upon arriving at the airplane, the safety driver will coordinate deboarding, check if the bus is empty and clean, and prevent passengers from walking freely on the platform.

The role of the safety driver in a system where autonomous buses are used in addition to manual bus operations is presented in Figure 49.

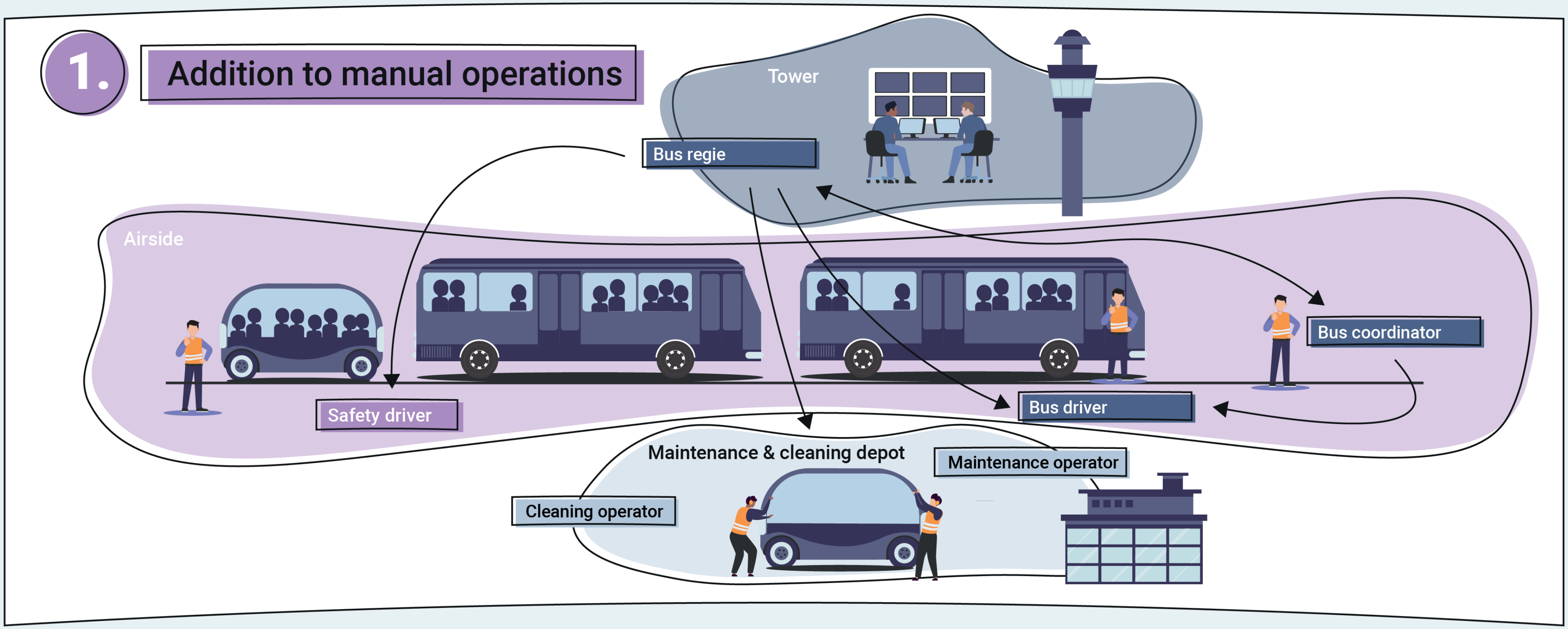


Figure 49: System design of the scenario where autonomous buses are an addition to manual bus operations. The arrows present the interaction between human operators.

7.1.2 Scenario 2: On-board service providing

As the autonomous bus system evolves, the need for a safety driver will diminish. However, Schiphol foresees that the human touch will continue to be a crucial aspect of their high-quality service proposition (RSG, 2020b). Additionally, experts have emphasized the necessity of initial human assistance to ensure a user-friendly experience and build passenger trust. To enhance the passenger experience, this scenario emphasizes on-board service, prioritizing direct interaction and engagement with passengers, thereby enhancing RSG's service proposition.

In this scenario, the role of a host or hostess is introduced, who focuses on providing attentive service on board.

When passengers arrive at the buses, the host or hostess will welcome them and assist with boarding. The human operators answer questions from passengers if necessary. They will help with luggage placement, ensure passengers fasten their seat belts, and close the bus doors. The host or hostess will stay on board as the autonomous buses depart.

During the commute, the host or hostess will ensure passenger comfort by making them feel at ease, answering questions, and educating them about the new technology. In case of an error, the remote supervisor will receive an alert and communicate with the host or hostess. The host or hostess will assess the situation, resolve minor malfunctions if possible, communicate with the supervisor, and continue the route. For major issues, the host or hostess will coordinate with the supervisor to send the bus to the maintenance depot and arrange for a backup bus. Upon arrival at the airplane, the host or hostess will assist with deboarding, wish passengers a safe flight, and stand ready for any further assistance or tasks as required. After all passengers have deboarded, the host or hostess will check the buses to ensure they are empty, clean, and free of forgotten luggage. If a bus requires cleaning, the host or hostess will notify the supervisors, who will send the bus to the maintenance depot and dispatch a backup bus. If luggage is left behind, the host or hostess will either return it to departing passengers or take it to Lost & Found for arriving flights. Once the buses depart, the host or hostess will rejoin the fleet and begin the next task.

The host or hostess also serves as a valuable source of passenger feedback and questions, which can be used to improve instructional videos shown on bus screens or in the terminal for future implications.

Initially, each bus may have a dedicated host or hostess to handle these tasks. As passenger trust in the system grows, this role can be gradually scaled back to one host or hostess per fleet, acting as the fleet coordinator. The fleet coordinator will have the same responsibilities but will accompany the first and last buses in the fleet instead of having one operator per bus.

The system design of the scenario with a host of hostess is presented in Figure 50.

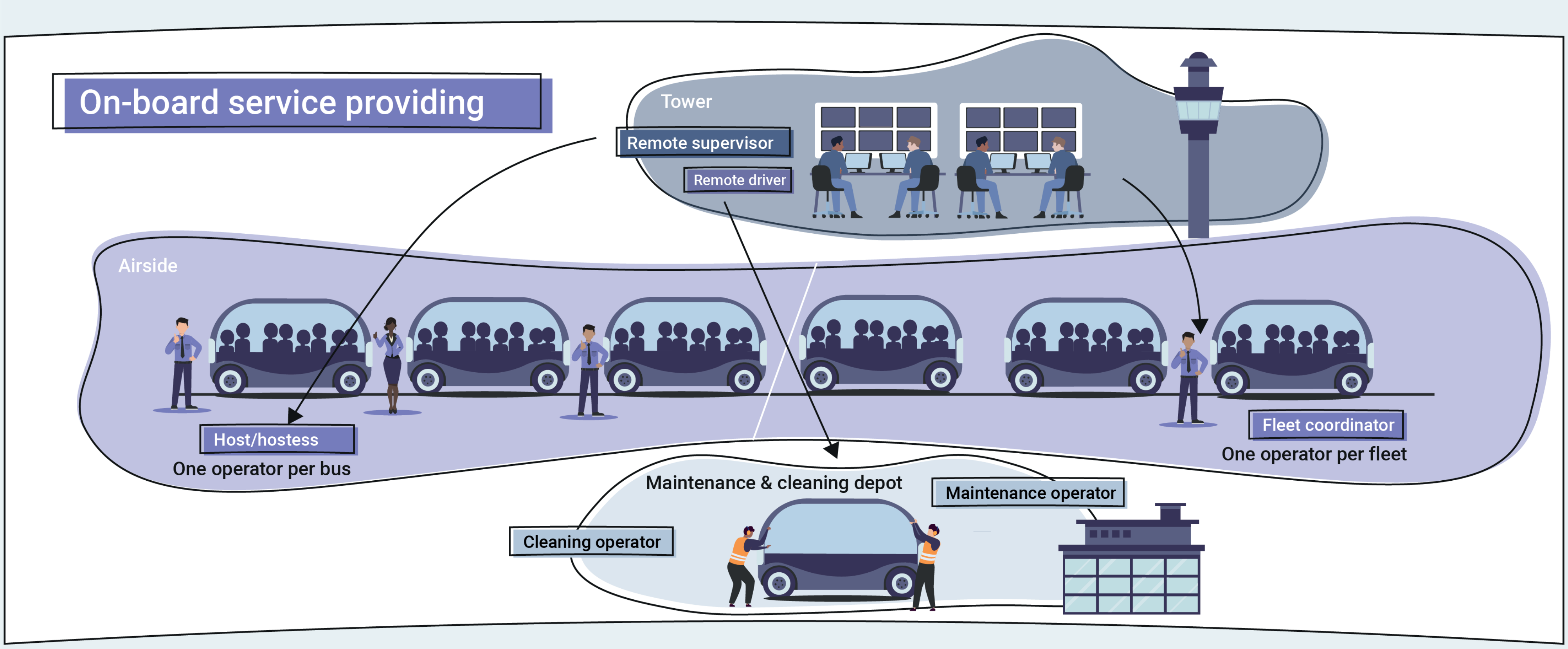


Figure 50: System design of the scenario where a host, hostess, or fleet coordinator accompanies the buses for on-board service providing. The arrows present the interaction between human operators.

7.1.3 Scenario 3: Boarding & deboarding assistance

In an autonomous bus system, instead of having a human operator accompanying the buses (i.e., host, hostess, or fleet coordinator), another option is to station them at fixed positions for boarding or deboarding. The bus will be monitored by remote supervisors during transit. This scenario introduces the role of the boarding assistant. Boarding assistants will guide passengers during the boarding process, while remote supervisors will monitor and control the buses from a centralized control room using interior cameras.

Boarding assistants will provide passengers with clear instructions and guidance throughout the boarding process. They will welcome passengers and will help with luggage. Additionally, the boarding assistants will step into the buses, educate passengers on how to fasten seat belts, and wish them a safe journey. Once all passengers are seated, the boarding assistants will step out of the buses and close the doors. During transit, safety instructions on the screen are crucial since there is no human operator physically present in the buses. Additionally, a two-way communication method is essential, to give passengers the possibility to get in contact with remote drivers and to answer urgent questions.

Remote supervisors will monitor the system and passenger behavior using interior cameras, depending on the LoA of the bus system. They will oversee multiple buses and intervene when necessary, meaning manually taking control of the buses to navigate obstacles or address errors. When manual takeover is required, the remote supervisor will inform passengers via the intercom, then use a joystick and exterior cameras to drive the bus manually. After reaching a safe area, the remote driver will switch the bus back to autonomous operation, allowing the bus to continue its journey.

Upon arrival, the assumption is made that the cabin crew can also have a proactive role in the deboarding process. When arriving at the airplane, the cabin crew will assist passengers with deboarding. Once the bus is clear, the cabin crew will close the doors, and the bus will proceed with its next task. This will require additional instructions and training for the cabin crew.

The system design of the scenario with (de)boarding assistants is presented in Figure 51.

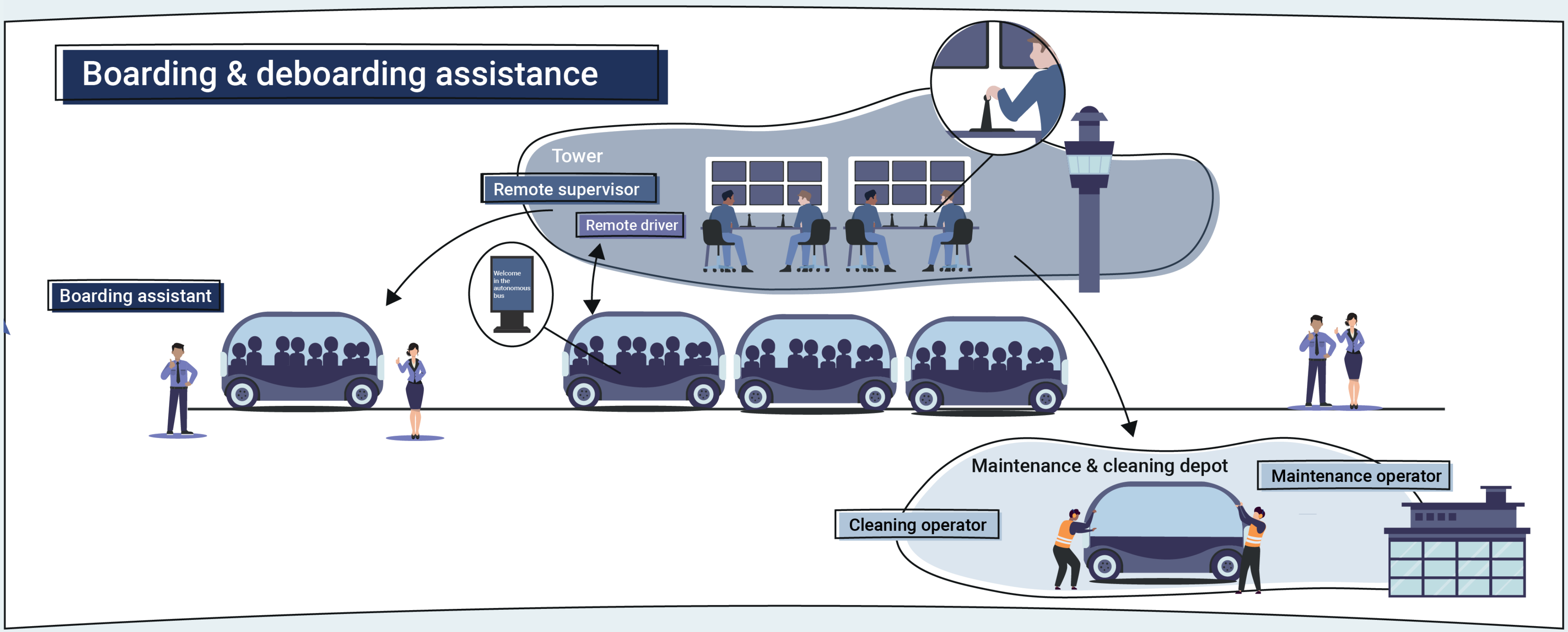


Figure 51: System design of the scenario where boarding assistants are located at fixed positions at the terminal to coordinate the boarding and deboarding procedure. The arrows present the interaction between human operators.

7.1.4 Scenario 4: assistance in case of emergency

In this scenario, the autonomous bus system operates autonomously with a low Level of direct interaction with human operators. The bus system operates with remote monitoring and assistance in case of emergency. Experts highlighted the need for direct communication with human operators during emergencies. Therefore, the role of rescuers is introduced, who remain essential as a backup process in case of an emergency. After the gate check-in, passengers will proceed to the autonomous buses, board, and fasten their seat belts. Interior sensors will detect if passengers have not fastened their seat belts or if luggage is too close to the door. An automated voice assistant will provide instructions to further inform passengers.

After the buses depart, the passengers in the bus will be monitored by the remote supervisors, with the help of sensors and interior cameras. In case of emergency during transit, remote drivers or supervisors will receive notification-based alerts and coordinate immediately with the rescuers, who will attend the scene with high priority. Passengers will be reassured by the remote supervisor via the intercom that help is on the way.

Upon arrival, rescuers will provide support to passengers and escort them to a designated safe area. A backup bus will be dispatched by the supervisors if needed, while minor malfunctions will be addressed by rescuers on-site. If the malfunction cannot be resolved by the rescuers, the bus will autonomously proceed to maintenance, and passengers will continue their journey on the backup bus.

Upon arrival, passengers will receive deboarding instructions from the automated voice assistant. Interior sensors will scan for cleanliness and forgotten items, and the voice assistant will automatically notify passengers if any luggage has been left behind. If necessary, supervisors will arrange for cleaning or maintenance at the depot before the bus resumes operations.

The scenario with rescuers in case of emergency is presented in Figure 52.

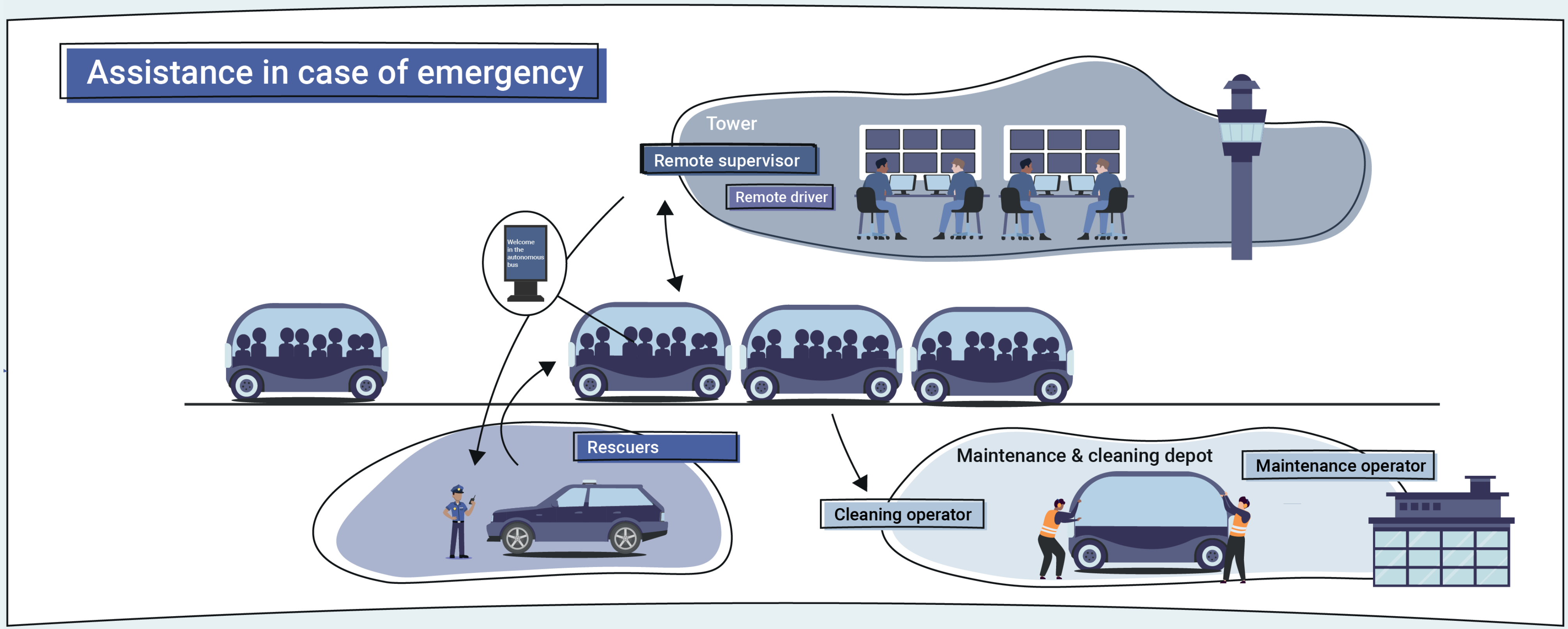


Figure 52: System design of the scenario where a host, hostess, or fleet coordinator accompanies the buses for on-board service providing. The arrows present the interaction between human operators.

7.3 Job description of future human operator roles

Based on the final concept, we can conclude that human operators play a crucial part in ensuring the success of autonomous transportation in airport operations. To elaborate on the jobs, duties, responsibilities, and job requirements of human operators, the role description of each role is presented in the following subsections.

7.3.1 The role of the bus driver, bus coordinator, and bus director

With the implementation of the autonomous bus system, the role of the bus driver and bus coordinator is gradually reduced. Despite some initial resistance from current bus drivers regarding the transition to new roles (Section 3.4), experts highlight the importance of being responsible for providing training opportunities to help the current operators develop into new roles like the remote supervisor.

In scenario 1, the role of the bus driver slightly changes when anticipating mixed traffic. Additionally, the role of the bus coordinator changes by communicating with the safety driver and assisting autonomous bus operations. The bus director also has additional duties and responsibilities, including monitoring alerts from autonomous buses, communicating with safety drivers, sending malfunctioning autonomous buses to the depot and dispatching backup buses.

7.3.2 The role of the safety driver

The safety driver is introducted in scenario 1. The job description of the safety driver and the included tasks are determined based on the current safety driver's experience at RSG, and the tasks of the current bus drivers, identified during shadow shifts (Section 3.3). The primary responsibility of the safety driver is to ensure passenger safety and intervene when necessary to prevent accidents or address unexpected situations by manually taking over the bus. Key tasks include ensuring onboard safety, communicating with passengers, helping them fasten seat belts, making them feel at ease, answering questions, educating passengers, and manually operating the bus when required.

Based on the experience of the current safety driver from RSG and the additional duties of the bus driver, job requirements for the safety driver are determined. From a service-oriented perspective, these include strong communication skills for interacting with passengers and coordinating with other operators, a welcoming attitude, and proficiency in both Dutch and English for international passengers. Communication with other operators is critical, especially during mixed traffic operations. Operational requirements include holding a driver's license, maintaining focus in unexpected scenarios, being comfortable with and having a basic understanding of autonomous technology, and being capable of manually operating the vehicle controls if necessary.

The job description of the safety driver is presented in Figure 53.

7.3.3 The role of the host, hostess, and fleet coordinator

In scenario 2, the host, hostess, and fleet coordinator is introduced. The main task of the host, hostess, or fleet coordinator is service providing to passengers. The human operator will accompany the bus or fleet to provide passenger service. From a service-oriented perspective, their main responsibilities include making passengers feel at ease, communicating with them, assisting them with luggage, and answering questions. Therefore, the host, hostess, or fleet coordinator needs strong communication skills for interacting with passengers and coordinating with other operators. Additionally, the host, hostess, or fleet coordinator should be welcoming, have a representative appearance, and be proficient in both Dutch and English, for international passengers.

Safety driver

Job description

A safety driver is responsible for monitoring the vehicle's operations, ensuring passenger safety, and intervening when necessary to prevent accidents or address unexpected situations.

Duties and responsibilities

- **Ensure safety on board**
- **Communication with passengers**
- **Manual takeover**
- **Let passengers put on seat belts**
- **Make passengers feel at ease**
- **Educate passengers**
- **Answer questions from passengers**

- Give boarding instructions
- Keep the buses clean
- Prevent passengers from moving freely
- Control passenger behavior
- Assess the situation
- Open & close the doors of the buses
- Check forgotten luggage
- Assist passengers with luggage
- Communicate with other human operators
- Check if the buses are empty
- Resolve small malfunctions
- Check if the buses are clean
- Assist during boarding and deboarding

Requirements

- Welcoming towards passengers
- Communication skills for passenger interaction and coordination with other human operators
- Open to learn new things
- Driver's license
- Ability to remain focused in unexpected scenarios
- Comfortable with autonomous technology with basic understanding of the system
- Capable of manually operating vehicle controls if needed
- Proficiency in both Dutch and English languages

Figure 53: job description of the safety driver

Host/hostess or fleet coordinator

Job description

A host/hostess or fleet coordinator accompanies the bus or a fleet to provide service towards passengers, answers questions from passengers, helps with luggage, educates passengers, and makes them feel at ease.

Duties and responsibilities

- **Make passengers feel at ease**
- **Communication with passengers**
- **Assist passengers with luggage**
- **Educate passengers**
- **Answer questions from passengers**
- **Intervene with the autonomous system**

- Resolve small malfunctions
- Let passengers put on seat belts
- Check if the buses are clean
- Assist during boarding and deboarding
- Give boarding instructions
- Keep the buses clean
- Prevent passengers from moving freely
- Control passenger behavior
- Assess the situation
- Open & close the doors of the buses
- Check forgotten luggage
- Check if the buses are empty
- Ensure safety on board

Requirements

- Strong communication skills for passenger interaction and coordination with other human operators
- Welcoming towards passengers
- Representative appearance
- Proficiency in both Dutch and English languages
- Comfortable with autonomous technology with basic understanding of the system
- Capable of manually operating vehicle controls if needed
- Driver's license

Figure 54: job description of the host/hostess or fleet coordinator

After passengers deboarded the buses, the host, hostess, or fleet coordinator's repsonsibility is to conduct a final check in the buses, to ensure the bus is clean, empty, and no luggage is forgotten. Although the host, hostess, or fleet coordinator does not need to be as technically oriented as the safety driver, they should still be able to assess the situation in case of a malfunction.

The job description of the host/hostess or fleet coordinator is presented in Figure 54.

7.3.4 The role of the boarding assistant

In scenario 3, the boarding assistant is introduced. The main task of the boarding assistant is to ensure a safe boarding and deboarding procedure. This includes providing (de)boarding instructions, helping passengers fasten their seat belts, and assisting with luggage. Job requirements for this role include strong coordination skills, communication skills for interacting with passengers and other operators, a welcoming attitude, and proficiency in both Dutch and English. Given the focus on ensuring a safe boarding procedure, adherence to safety protocols and regulatory requirements is crucial.

The job description of the boarding assistant is presented in Figure 55.

7.3.5 The role of the rescuer

In scenario 4, the rescuer is introduced. Rescuers respond immediately when buses have an emergency. They guide passengers to a safe meeting area to wait for a backup bus, resolve minor malfunctions on-site, and communicate with the remote supervisor and other operators. Rescuers need to stay focused in unexpected scenarios, be comfortable with autonomous technology, understand basic system operations, adhere to safety protocols at all times, and hold a driver's license for airside driving.

The job description of the rescuer is presented in Figure 56.

(de)Boarding assistant

Job description

A (de)boarding assistant stands at fixed positions outside of the terminal and ensures a safe (de)boarding procedure, including giving (de)boarding instructions, helping passengers to fasten the seat belts, and assisting passengers with luggage.

Duties and responsibilities

- **Assist during boarding and deboarding**
- **Give boarding instructions**
- **Assist passengers with luggage**
- **Communication with passengers**
- **Let passengers put on seat belts**
- **Make passengers feel at ease**
- Check if the buses are clean
- Control passenger behavior
- Open & close the doors of the buses
- Check forgotten luggage
- Keep the buses clean
- Prevent passengers from moving freely
- Answer questions from passengers

Requirements

- Communication skills for passenger interaction and coordination with other human operators
- Strong coordination skills
- Adherence to regulatory requirements and company policies regarding safety procedures
- Welcoming towards passengers
- Proficiency in both Dutch and English languages

Figure 55: job description of the (de)boarding assistant

Rescuers

Job description

A rescuer immediately goes to the bus when an emergency with the autonomous bus occurs, to guide passengers to the meeting area. While waiting for a back up bus, the rescuer tries to solve the malfunction on-site.

Duties and responsibilities:

- **Immediately go to the autonomous bus after an emergency stop occurs**
- **Guide passengers to the meeting area to wait for a back up bus**
- **Resolve small malfunction on-site**
- Communication with passengers
- Communication with remote driver

Requirements

- Comfortable with autonomous technology with basic understanding of the system
- Ability to remain focused in unexpected scenarios
- Communication skills for passenger interaction and coordination with other human operators
- Adherence to safety protocols and regulations governing autonomous vehicle operation
- Proficiency in both Dutch and English languages
- Driver's license

Figure 56: job description of the rescuer

7.2.6 The role of the remote supervisor

Remote supervisors oversee the autonomous bus operations from a control room. Responsibilities of the remote supervisor include monitoring cameras, assessing situations when errors occur, and communicating with passengers in the bus when needed. This requires advanced knowledge of autonomous systems, and strong analytical skills to interpret data and make informed decisions. Remote supervisors must adhere to safety protocols and regulations. Communication with passengers via intercom requires proficiency in both Dutch and English.

The job description of the remote driver is presented in Figure 57.

When prefered, the remote supervisor could intervene when necessary by manually taking control using a joystick and exterior cameras. In this case, proficiency in remote monitoring and control technologies is required or the drivers must undergo specialized training in remote driving techniques. Additionally, a driver's license would be necessary.
The remote driving capability is exluded from the scenarios, since participants during the expert interviews expressed mixed feelings towards remote driving. However, this could be considered in future implications.

Remote supervisor

Job description

A remote supervisor is responsible for monitoring the autonomous bus system from a remote location, by checking the cameras and assessing alert-based notifications. When a malfunctions occurs which is unable to be resolved by the system itself, the supervisor assesses the situation and provide solutions while upholding safety standards.

Duties and responsibilities

- **Monitor alerts**
- **Assess the situation**
- **Watch the cameras**
- **Communication with passengers**
- Control passenger behavior
- Communication with other human operators

Requirements

- Advanced knowledge of autonomous systems and their operation
- Proficiency in remote monitoring and management systems
- Ability to remain focused and attentive during extended periods of remote operation
- Excellent communication skills for coordinating with on-site teams
- Strong analytical skills to interpret data
- Ability to make quick and accurate decisions in response to emergent situations or technical issues
- Technical aptitude to resolve issues remotely
- Knowledge of safety protocols and regulations governing autonomous vehicle operations
- Proficiency in both Dutch and English languages

Figure 57: job description of the remote supervisor

7.4 Creating the speculative design artifact

The future scenarios presented in this Chapter are further developed into an animation video, which serves as a speculative design artifact. Speculative design is a research approach that focuses on envisioning and exploring possible futures. It involves creating artifacts, scenarios, and narratives to represent alternative futures. These artifacts are not intended to be practical solutions but are instead used as tools for reflection, debate, and inquiry (Dunne & Raby, 2013).

Studies show that speculative design is a suitable method to bridge differences between participants coming from a variety of backgrounds (Auger, 2013), to find creative ways for people with non-technical backgrounds to get engaged with abstract topics (Yams & Muñoz, 2021). This would be useful for discussing possible human operator roles in an autonomous bus system with people from various backgrounds. Additionally, speculative design is suitable to use as a probe tool to explore possible future scenarios (Al-frink et al., 2023).

The method of speculative design was chosen for this research because it effectively explores and illustrates potential future human operator roles in an autonomous bus system in Autonomous Airside Operations. This method encourages discussion and reflection on potential future scenarios. It provides a safe space to explore potential futures and gathers valuable insights into stakeholder perceptions. Additionally, animations make complex concepts easier to understand, helping RSG to better envision future possibilities for the future human operator role in an autonomous bus system in Autonomous Airside Operations.

For the speculative design artifact, an animation video is chosen. With a animation video, different scenarios can be presented in an engaging and accessible way.

7.4.1 The prototype

Based on the system designs of future scenarios where human operators remain crucial in an autonomous bus system (Section 7.1) and the job descriptions of future human operator roles (Section 7.2), a storyboard is designed for an animation video. The video is created, which serves as the first prototype. The storyboard of the prototype is presented in Figure 58.

7.4.2 Testing the prototype

The animation video is assessed by two fellow IDE students. The prototype is examined on the following factors: (1) understandability of the concept and (2) biases in the concept.

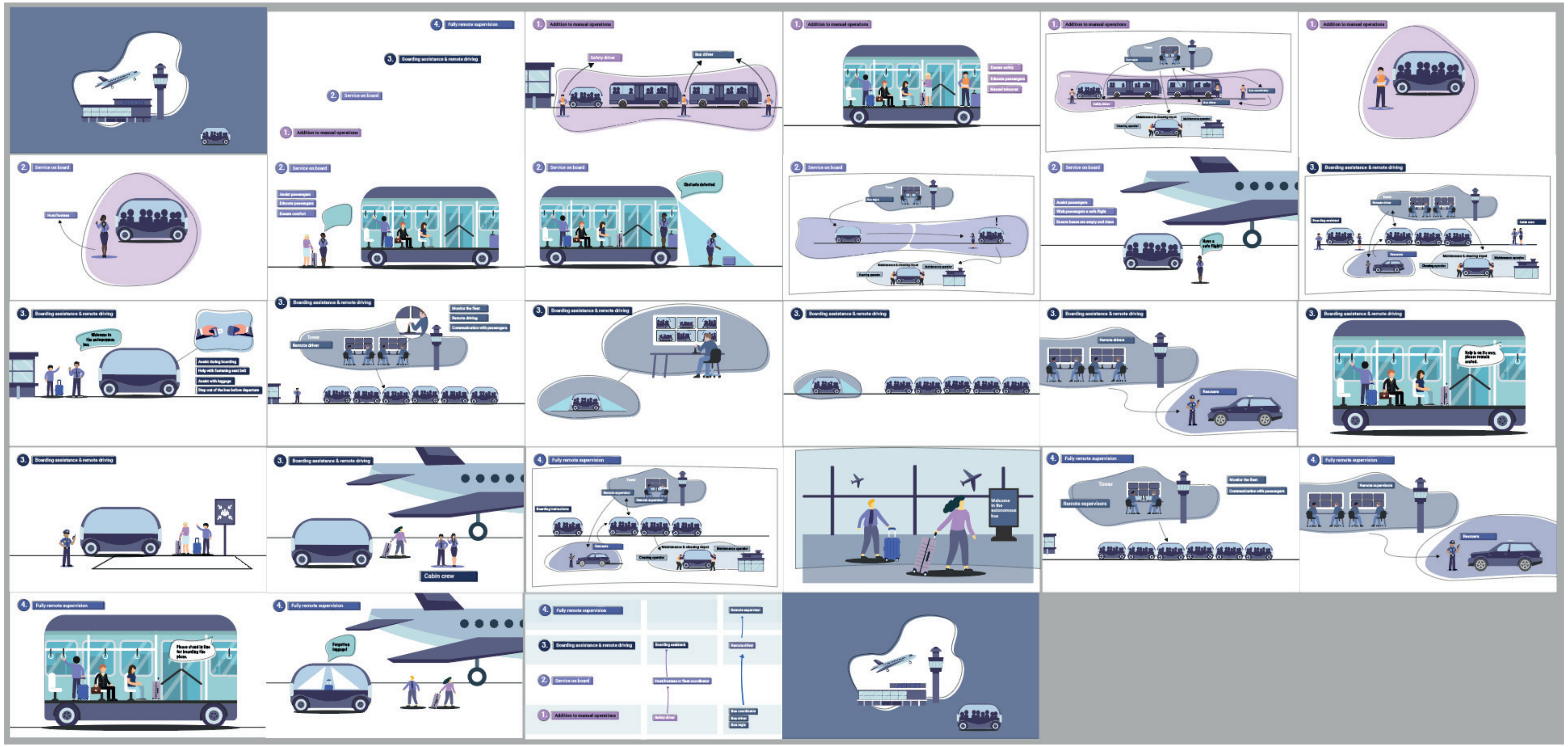


Figure 58: Storyboard for the prototype

7.4.3 Findings

Based on the tests of the prototype, key findings were identified. Following this, the final concept was designed and animated, as presented in Section 7.4. The findings of the prototype test are as follows:

- The video conveys a large amount of information simultaneously, making it difficult to understand. Participants of the prototype test suggested creating individual animations for each scenario.
- The animation is long (5.5 minutes). The concept would be clearer if the animation videos were approximately 1 minute per scenario.
- Adding subtitles would enhance the clarity of the story.
- One participant mentioned to emphasize the day-to-day activities of the human operators, instead of focussing on the system design.
- No bias was found in the animation video. Participants perceived the story as neutral and informative. However, the supervisory team suggested making the characters in the videos less stereotypical and as neutral as possible to minimize bias. Additionally, they advised to remove the background music, as the current music was perceived as overly optimistic.

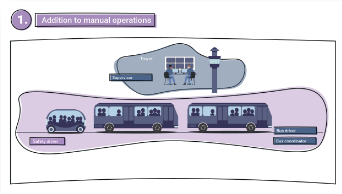
Based on these findings, an iteration was made for the final design.

7.5 Final storyboard design

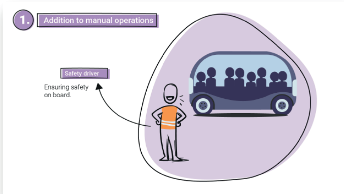
After iterating on the final storyboard design (Appendix D), this section presents the speculative design artifacts in the form of animation videos. Each video depicts a future scenario where human operators remain essential in an autonomous bus system. The future roles of human operators are explained by showcasing their tasks, required skills, and interactions. The storyboards for the following four scenarios are presented: (1) Addition to manual operations with the role of the safety driver in Figure 59; (2) On-board service providing with the role of host/hostess or fleet coordinator in Figure 60; (2) Boarding & deboarding assistance with the role of (de)boarding assistant in Figure 61; and (3) Assistance in case of an emergency with the role of rescuer in Figure 62.

7.5.1 The storyboard of the animation for the role of safety driver

Intro.

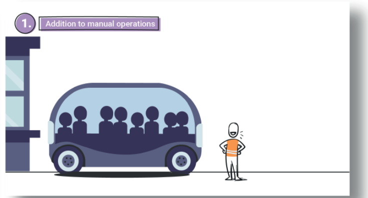


The implementation of an autonomous bus system in airside takes a step-by-step approach. As a first step, manual buses continue their service with autonomous buses as an addition to manual operations.

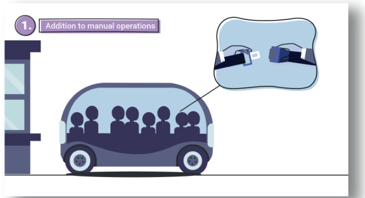


To operate the autonomous bus, this scenario introduces a safety driver.

The passengers line up in the terminal and walk towards the buses. The safety driver welcomes the passengers.



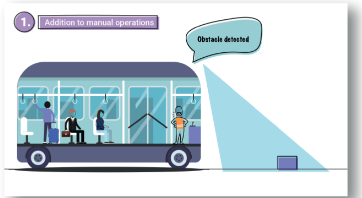
When all the passengers board the bus, the safety driver accompanies the bus.



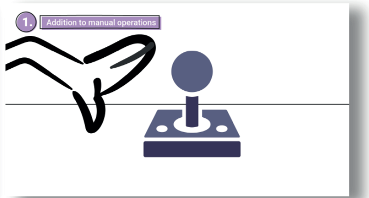
The operator makes sure that every passenger puts on the seat belts.

During transit, the operator monitors the vehicle's operations and ensures passenger safety.

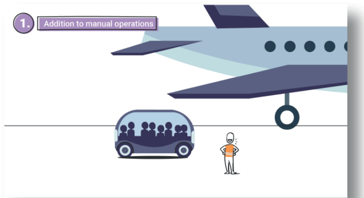
Also, the safety driver educates passengers about the autonomous technology.



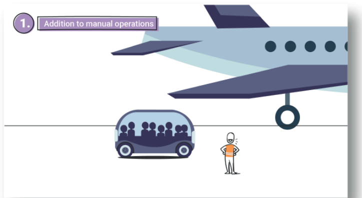
When an issue occurs, the safety drvier assesses the situation and communicates with the remote supervisor.



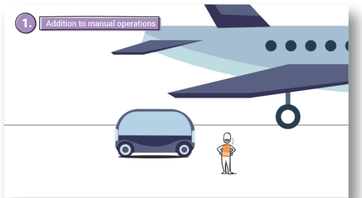
After that, the operator manually takes over the bus with a joystick, to move past an obstacle or to drive to a safe area.



Upon arriving at the airplane, the safety driver will coordinate the deboarding procedure.



The human operator checks if the bus is empty and clean, and prevents passengers from walking freely on the platform.

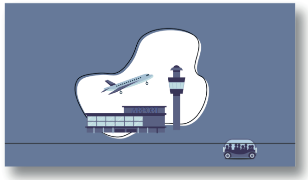


After all passengers are deboarded, the safety driver steps on the bus and starts the upcoming task.

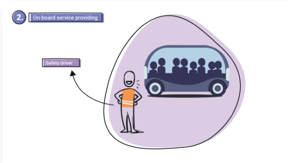
Outro.

Figure 59: Storyboard for the animation video of the safety driver scenario

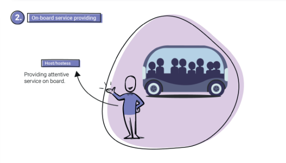
7.5.2 The storyboard of the animation for the role of host/hostess



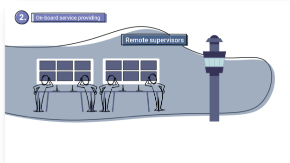
Intro.



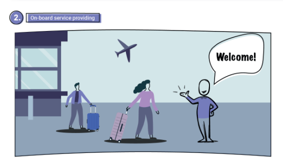
As the autonomous bus system advances, a safety driver will no longer be necessary.



To ensure a user-friendly experience and enhance attentive service, scenario two introduces an on-board service: the host.

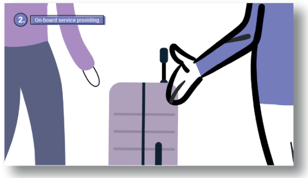


In this scenario, supervisors monitor bus operations from a remote location.



The host or hostess welcomes passengers as they walk from the terminal to the autonomous buses.

The human operator takes on responsibilities such as answering passenger questions.



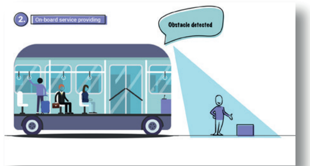
And assisting passengers with their luggage.

After all passengers have boarded the bus, the host or hostess accompanies the bus and closes the doors.

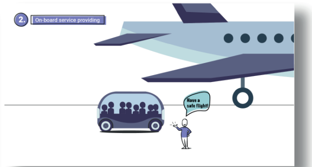
The buses then drive to the airplane.

During the commute, the human operator answers questions about autonomous technology.

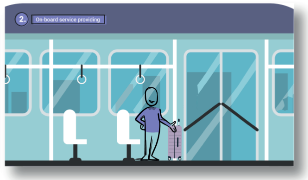
Or engages with them about their upcoming flight.



In case of issues, the host or hostess assesses the situation, resolves minor malfunctions if possible, communicates with the bus director, and continues the route.

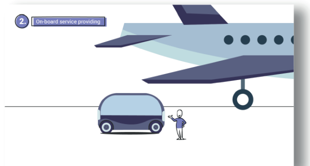


Upon arrival at the airplane, the human operator stands besides the bus and wishes passengers a safe flight.

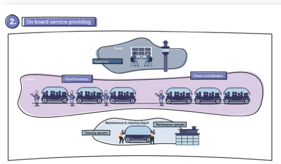


After the last passenger departs the bus, the host or hostess inspects all the buses to ensure they are empty and clean. If the host or hostess finds forgotten luggage on one of the buses, they give it to the cabin crew to return to the passenger.

If the human operator notices a spilled drink in the bus, they call the supervisor to send the bus to the maintenance depot and request a back-up bus.



Afterwards, the host or hostess rejoins the bus for the next task.

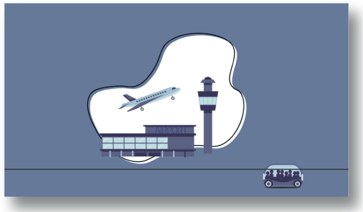


As passenger trust in the system grows, this role can be gradually scaled back to one host or hostess per fleet, acting as the fleet coordinator. The fleet coordinator will have the same responsibility but will accompany the first and last bus in the fleet instead of having one operator per bus.

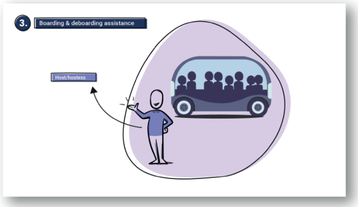
Outro.

Figure 60: Storyboard for the animation video of the host/hostess scenario

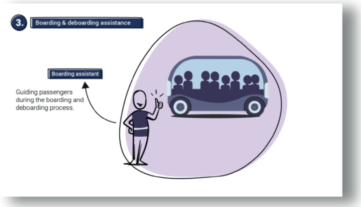
7.5.3 The storyboard of the animation for the role of boarding assistant



Intro.

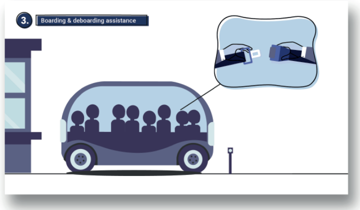


Instead of having a human operator accompany the buses, another option is to station them at fixed positions for boarding and deboarding.



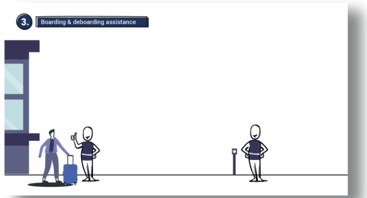
This scenario introduces the role of the boarding assistant, who will guide passengers during the boarding and deboarding process.

As passengers walk from the terminal to the autonomous buses, the boarding assistants welcome them.

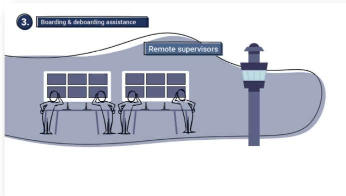


One boarding assistant provides clear seat belt instructions.

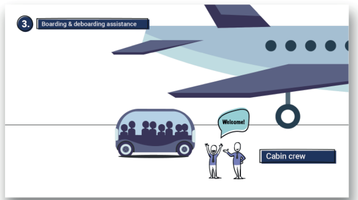
The human operator checks if the bus is ready to depart, steps out, closes the doors, and sends the bus toward the airplane.



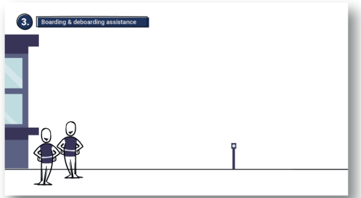
Another boarding assistant holds back passengers until the next bus arrives.



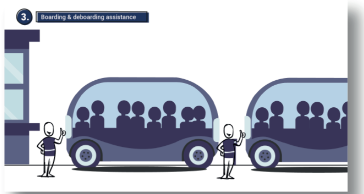
During transit, supervisors monitor the bus using interior cameras and a two-way intercom to communicate with passengers if necessary.



When the buses arrive at the airplane, the cabin crew oversees the deboarding procedure.



Meanwhile, the boarding assistants wait for the next arriving flight.

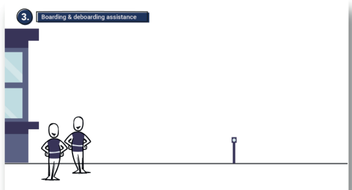


When the buses arrive, the human operators ensure a safe and comfortable deboarding.

One boarding assistant brings a stroller to a passenger with a child.

After that, the human operator checks if the buses are empty, clean, and free of forgotten luggage.

Another boarding assistant checks if all passengers have entered the terminal and asks any remaining passengers to follow the others inside.



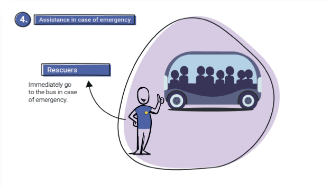
After the deboarding procedure is completed, the boarding assistants wait for the next departing flight.

Outro.

Figure 61: Storyboard for the animation video of the boarding assistant scenario

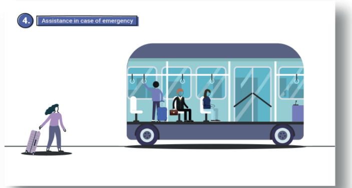
7.5.4 The storyboard of the animation for the role of rescuer

Intro.

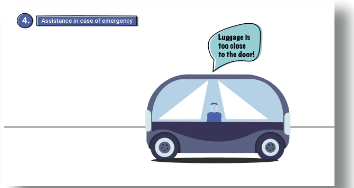


In this scenario, human operators remain essential as backup process in case of emergency.

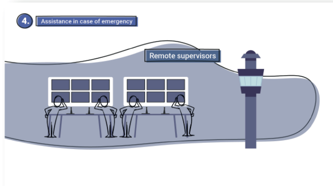
Passengers line up in the terminal. While waiting, a boarding instruction video is presented.



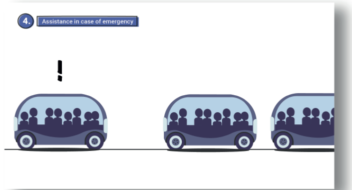
The passengers walk outside of the terminal and board the autonomous buses.



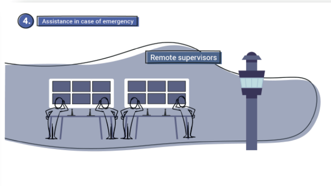
Interior sensors will detect if passengers have not fastened their seat belts or if luggage is too close to the door.



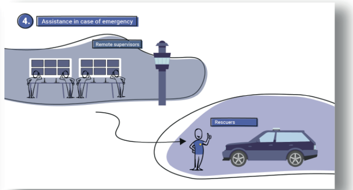
After the buses depart, the passengers in the bus will be monitored by the remote drivers or supervisors, with the help of sensors and interior cameras.



During transit, one of the buses makes and emergency stop.

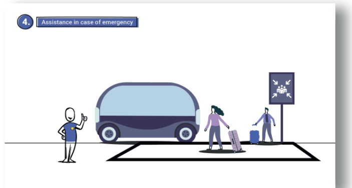


Supervisors will receive notification-based alerts and assess the situation.

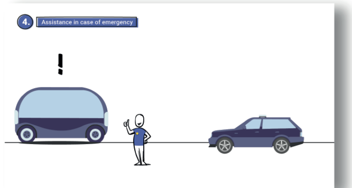


They coordinate immediately with the rescuer, who attends the scene with high priority.

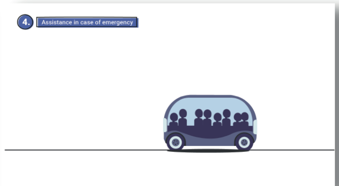
Meanwhile, passengers are reassured by the remote supervisor via the intercom that help is on the way.



Upon arrival, the rescuers support passengers and escort them to a designated meeting area. A backup bus is dispatched by the supervisors.

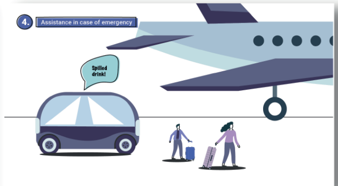


Meanwhile, one rescuer tries to resolve a small malfunction on-site. If it cannot be resolved, the bus is sent to the maintenance depot.

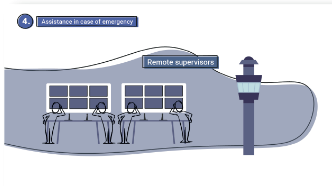


The backup bus arrives and the bus continues toward the airplane.

Upon arrival, passengers receive deboarding instructions through automated voice assistance.



When passengers are deboarded, sensors detect a spilled drink.



The supervisors get a signal, assesses the situation, and sends the bus towards the cleaning staff at the depot.

Outro.

Figure 62: Storyboard for the animation video of the rescuer scenario

8. Discussion

This chapter discusses the research findings, its contribution to literature and to Royal Schiphol Group (RSG), the generalisability of the research, its limitations, and recommendations for future work. Section 8.1 presents a summary of results to answer the research questions. Section 8.2 shows the results' contribution to existing literature and to the organisation. Section 8.3 examines the generalisability of the research. Additionally, limitations of the study are presented in Section 8.4. Lastly, a proposal for future work is shown in Section 8.5.

Aim: Discuss the key research findings, contribution to literature and RSG, generalisability, limitations of the research, and future work.

Source: photo courtesy of RSG (n.d)

8.1 Summary of the results

The aim of this study was to design the future roles of human operators are in an autonomous bus system in Autonomous Airside Operations. To answer this question, the study has been three-fold: (1) to explore prior work on the integration of automation in workplaces and the use of design methodologies to design future roles; (2) to understand how the operators of the current bus system operate in the airside operations; and (3) to design future human operator roles in an autonomous bus system in autonomous airside operations. The outcome of the study to this end consists of a speculative design concept in the form of animation videos. These videos show possible future scenarios of human operators in an autonomous bus system in Autonomous Airside Operations.

In this section, we refer back to the results of the context study, expert interviews, and the final design, to see how the following research question is answered:

RQ: **What are the possible future roles of human operators in an autonomous bus system in Autonomous Airside Operations?**

8.1.1 The use of human-centered principles and speculative design in designing future roles

The traditional Job Characteristics Model (Hackman & Oldham, 1976) has long been a cornerstone in designing human roles. However, with the integration of automation in workplaces, this model has become less applicable. The core components of the model, which include skill variety, task identity, task significance, autonomy, and feedback, are often altered or diminished in automated environments (Waschull et al., 2020; Reil & Leyer, 2021; Leyer et al., 2018; Morgenson & Humphrey, 2008).

This research focussed on developing a human-centered framework for future human operator roles in automated workplaces. Following such a framework, future roles are further determined in a specific use case: the autonomous bus system in airside operations. Human-centered principles (Zijlstra et al., 2014) are combined with the Job Characteristics Model (Hackman & Oldham, 1976), and a speculative design approach to create a framework for designing future roles.

First of all, Human-centered design is an iterative design approach that puts the needs, wants, and behaviors of users at the forefront of the design process (Norman, 2013). It seeks to create solutions that are intuitive, usable, and meaningful to the people who will interact with them (Zijlstra et al., 2014). By applying HCD principles, we ensure that the roles designed are tailored to the specific context and needs of the user. This approach involves extensive emphasizing with the context to gather comprehensive insights into the current operations.

Second, the Job Characteristics Model (Hackman & Oldham, 1976), despite its limitations in automated settings, provides valuable insights into identifying the key elements of this model: skill variety, task identity, task significance, autonomy, and feedback. Insights can be gathered about these elements in the current human operator roles to understand the current bus operations and to ensure that the designed roles continue to provide meaningful and engaging work for human operators.

Lastly, speculative design is a research method that focuses on envisioning and exploring possible futures, by creating artifacts, scenarios, and narratives. These artifacts are not practical solutions but tools for reflection, debate, and inquiry (Dunne & Raby, 2013). This approach allows us to explore potential future roles in an automated system and address contextual implications, to make the scenarios more tailored to the context. As Palanque et al. (2021) mentioned, understanding context-specific implications can is essential for the successful implimentation of automated systems.

Based on prior work, including studies by Fox (2023), Lin and Long (2023), Yams and Muñoz (2021), and Grafström et al. (2022), we adopted steps to apply speculative design in designing human-centered future roles. By combining these approaches, a robust framework (Figure 63) is developed for designing future human-centered roles in automated workplaces.

In conclusion, this framework is designed because the successful integration of technology relies not only on its technical capabilities but also on human operators, who will work in and interact with, in this case, an autonomous bus system. By placing humans at the center of the design process, a valuable future human operator role can be created, which remains crucial in an automated workplace. This approach aligns closely with human-centered design principles and ensures that the design of future human roles contributes to a human-focused automated workplace, despite the evolving landscape of autonomous technology.

The first 4 steps in the framework are followed in this study, from empathizing with the current context and stakeholders, defining a design challenge, generating ideas for future scenarios based on expert interviews, and prototyping speculative artifacts.

Framework for designing human-centered roles using speculative design

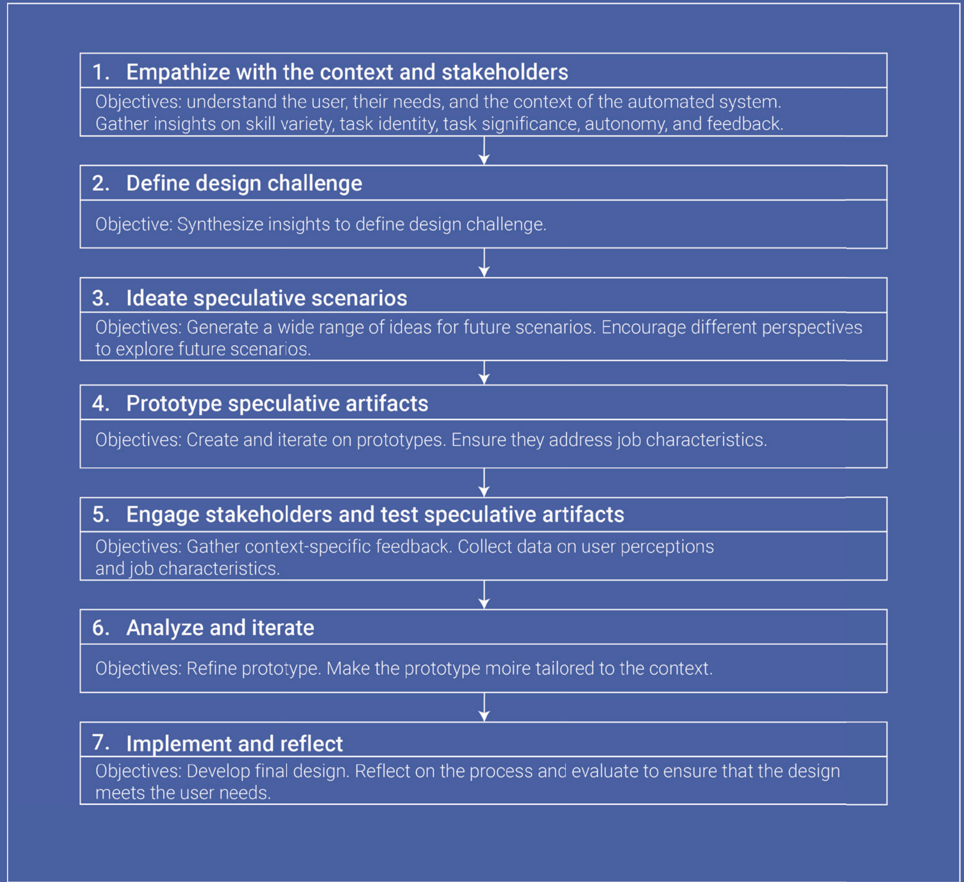


Figure 63: Framework for designing human-centered roles. This framework is a synergy from the human-centered design approach (Zijlstra et al., 2014), the Job Characteristics Model (Hackman & Oldham, 1976), and speculative design principles (Fox , 2023; Lin and Long, 2023; Yams and Muñoz, 2021; and Grafström et al., 2022).

8.1.2 Context study and expert interviews: future scenarios where human operators play a crucial role

This study explored the future roles of human operators in the context of an autonomous bus system, particularly focusing on Schiphol Airport's airside operations. The findings from both the context study and the expert interviews study highlighted the necessity of human operators in scenarios where the autonomous bus system has its limitations. Based on the context study, 5 current responsibilities of human operators were identified besides driving-related tasks: (1) to coordinate and execute of the boarding and deboarding procedure; (2) to serve as a social actor who provides service to passengers; (3) to ensure safety; (4) to adapt to unexpected scenarios; and (5) to conduct the final check if the buses are empty, clean, and no luggage is forgotten.

Additionally, the expert interview study revealed 5 additional future human operator responsibilities in Autonomous Airside Operations: (1) to ensure safety in a regulated and traffic-intense airport environment; (2) to ensure smooth operations in mixed traffic, during the step-by-step implementation of an autonomous bus system; (3) to operate in scenarios where the autonomous bus system reaches its limitations; (4) to provide on-site human intervention and remote supervision; (5) to enhance passenger experience and control passenger behavior.

The insights from both the context research and expert interviews uncovered potential future scenarios where human operators have essential roles in Autonomous Airside Operations. The synthesis of these insights led to the identification and design of four possible future scenarios, each with a specific human operator role, which is presented in Table 2.

It is important to note that more scenarios could have been designed. However, the aim of this study is to contribute to the ongoing conversation about human-centered design in automation, by creating tangible examples in a specific use case. The aim of the scenarios is to showcase tangible examples with high detail, to engage with stakeholders in the organization, to identify contextual implications, and to make the scenarios more tailored to the specific context of the airside.

No.	Current human operator responsibilities, besides driving-related tasks	Future human operator responsibilities in Autonomous Airside Operations:	Scenario	Human operator role
1	Ensure safety	Ensure safety in a regulated and traffic intense airport environment; Ensure smooth operations in mixed traffic, during the step-by-step implementation of an autonomous bus ssytem in manual operations	Addition to manual operations	Safety driver
2	Serve as a social actor who provides service to passengers	Enhance passenger experience and control passenger behavior	On-board service providing	Host/hostess or fleet coordinator
3	Coordinate and execute the boarding and deboarding procedure	Enhance passenger experience and control passenger behavior	Boarding & deboarding assistance	(De)boarding assistant
4	Ensure safety; Adapt to unexpected scenarios	Ensure safety in a regulated and traffic intense airport environment; Provide on-site human intervention and remote supervision	Assistance in case of emergency	Rescuer

Table 2: Potential future scenarios of an autonomous bus system in Autonomous Airside Operations with the associated human operator roles

Dimensions of future scenarios

The future scenarios designed in this study were characterized by two dimensions that were essential in understanding the positioning of the different scenarios in relation to each other:

- Level of automation (LoA): This dimension considers the expected LoA, referring to the evolving technological capabilities of the automated system, based on insights from the expert interviews.

- Level of direct human operator interaction (LoI): With the level of direct human operator interaction, we refer to how much face-to-face interaction passengers have with a human operator in the scenario.

A matrix is created to assess the different scenarios on these dimensions (Figure 54).

Additional considerations

While the designed scenarios focused on specific dimensions, other potential dimensions could also be significant in shaping future human operator roles:

- Level of passenger trust: Trust is a dynamic factor that can evolve with increased exposure to and experience with autonomous systems. Future designs could incorporate high and low levels of passenger trust in future scenarios since this would impact the role of the human operators and the LoI in the scenarios.

- Level of the driving element: In one of these scenarios, the driving element remains present (i.e., the safety driver has the capability to manually take over the bus). However, the extent of the driving element in remote supervisory roles is not explicitly addressed. Future designs could further develop and clarify the remote driving capabilities.

Level of Automation	Low interaction (Remote Supervision)	Medium interaction (Occasional assistance)	High interaction (Constant on-board presence)
Low (Manual)	Autonomous bus as addition to manual operations with remote supervision	Autonomous bus as addition to manual operations with assistive operators at fixed positions	Autonomous bus as addition to manual operations with on-board conductor to manually take-over
Medium	Autonomous driving with remote supervision who could interrupt	Autonomous driving with assistive operators at fixed positions who could interrupt	Autonomous driving with on-board service operator who could interrupt
High (Full automation)	Fully autonomous with remote monitoring and assistance in case of emergency	Fully autonomous with assitive operators at fixed positions outside of the buses	Fully autonomous with on-board service operator

Figure 64: Custom matrix for the LoA and LoI of an autonomous bus system

8.1.3 Speculative design concept videos: possible future human operator roles

Based on the future scenarios, presented in Table 2, a speculative design concept is designed in the form of 4 animation videos. Each animation video shows one future scenario and the associated future role, including its tasks, skills, and interactions.

The first animation video shows the role of the safety driver in a scenario where the autonomous bus serves as an addition to the manual bus operations. First, the video shows that a safety driver is responsible for ensuring safety in an autonomous bus operating in mixed traffic.

The second animation video presents an on-board service scenario with the role of the host or hostess. The video starts with presenting the tasks of the host or hostess during the boarding procedure, which includes welcoming passengers, answering questions from passengers, and assisting passengers with luggage. After that, the animation shows how the host or hostess accompanies the bus and drives towards the airplane. During the commute, the human operator has conversations with passengers, answers further questions, explains how the autonomous technology works, assesses the situation in case of an issue, and resolves minor malfunctions. The close communication with the remote supervisor is also presented. Lastly, the video shows how the host or hostess wishes passengers a safe flight while deboarding the bus and checks if the bus is empty, and clean, and if no luggage is forgotten.

The third animation video shows the role of the (de)boarding assistant. First it shows the tasks of the boarding assistant during the boarding procedure, which include welcoming passengers, guiding them inside the buses, providing seat belt instructions, closing the doors, and sending the buses toward the airplane. After that, the video shows tasks during the deboarding procedure, including ensuring a safe deboarding procedure, assisting passengers with wheelchairs or strollers, checking if the buses are empty, and clean, and if no luggage is forgotten, and reassuring that passengers do not walk freely on the airside.

The fourth animation video presents a scenario where assistance by the rescuer is required in case of an emergency. First, it shows how passengers board the bus without any human interaction but are being monitored remotely with the help of sensors. After that, the video shows how remote supervisors and rescuers operate if one bus makes an emergency stop. The video closes with passengers deboarding the buses with the help of automated voice assistance, monitored by cameras and sensors.

8.2 Contribution

8.2.1 To Academia

Future human operator roles in automated workplaces

Prior research has primarily focused on evaluating the impact on human operators after the implementation of automated systems. Research showed several factors that negatively impact how human operators perceive working with automated systems: lack of trust, misunderstanding of how the system functions, accountability gap between humans and automated systems, and reduced level of decision-making authority and control (Höddinghaus et al., 2021; Lee, 2018; Panchal, 2023; Chu et al., 2020; Langer & Landers, 2021; Raji et al., 2020).
However, a proactive, human-centered design of human operator roles is underexplored. This research contributed to the underexplored human-centered principles when designing future human operator roles in automated workplaces.

Additionally, Palanque et al. (2021) stated that the interpretation of human operator roles in autonomous workplaces is highly context specific and requires further research. Parker & Grote (2022) also highlighted the need for a context-specific study. This research builds on their work by providing a specific case study in the form of the autonomous bus system in Autonomous Airside Operations at Schiphol Airport. It underscores the importance of tailoring human roles to specific automated contexts to ensure the successful implementation of an autonomous system (Xing et al., 2021).

This research aimed to get a deep understanding of the current bus operations, by conducting in-depth literature research, context study, and expert interview study, before envisioning future human operators in autonomous operations. This approach ensured a grounded foundation to design tailored future scenarios and future human roles.

The findings align with existing literature on the role of human operators in automated systems, emphasizing the necessity of human intervention in scenarios where autonomous systems reach their limitations. The specific scenarios explored in this study, such as assistance in case of an emergency and boarding assistance, reinforce the concept that human roles remain essential in automated environments (Chu et al., 2023; Roto et al., 2019; Bradshaw et al., 2013; Parker & Grote, 2022; Roto et al., 2019).

In conclusion, this research contributes to the ongoing conversation by providing specific insights into the context-dependent nature of human roles in autonomous systems, reinforcing the need for a tailored approach when designing a future role in such environments. By designing human operator's roles in a specific context, these insights can be used as an addition to ultimately develop a human-centered framework for future roles.

Job Characteristic Model (Hackman & Oldham (1976)

Additionally, the study revisits Hackman and Oldham's Job Characteristics Model (1976) in the context of automated workplaces. By identifying how automation affects key job characteristics—such as skill variety, task identity, task significance, autonomy, and feedback—the research highlights the need to adapt these elements to maintain job quality and satisfaction in automated environments. This adaptation is crucial as traditional job design models may no longer be fully applicable due to the evolving nature of future work in automated workplaces.

Human-centered design methodology

In this research, a human-centered design approach (Zijlstra et al., 2014) to designing future human roles in automated environments is introduced and motivated through a case study of human operators in an autonomous bus system in Autonomous Airside Operations. This research contributes to the human-centered design (HCD) approach (Zijlstra et al., 2014), by understanding the current manual operations and combining insights from the literature study, context study, and expert interviews. This resulted in accurate and tangible answers and input for future autonomous bus scenarios and human roles. Utilizing this knowledge in the design of future roles in automated environments is a step forwards towards successful human-centered automation. However, much work still needs to be done since this research only provides insights on the specific use case of an autonomous bus system in airside operations and is not generalizable for human-centered automation.

Speculative design as a research method

Additionally, the use of speculative design as a research method allowed for the exploration of future scenarios and roles, providing a creative and open-ended approach to envision the integration of autonomous systems in the airside context. This approach contributes to the emerging field of speculative design (Fox, 2023; Lin and Long, 2023; Yams and Muñoz, 2021; and Grafström et al., 2022), by demonstrating its practical application in a complex, highly regulated, and multi-stakeholder environment.

Created a framework for designing human-centered future roles

Lastly, the designed framework integrates the elements of a human-centered design approach (Zijlstra et al., 2014), the Job Characteristics Model (Hackman and Oldham 1976), and the speculative design principles, to offer a comprehensive approach to designing and implementing successful human-centered roles in automated workplaces. By considering human factors, job characteristics, and speculative scenarios, the framework provides a robust tool for both researchers and practitioners aiming to optimize the integration of automated systems in workplaces.

8.2.2 To Royal Schiphol Group

For Royal Schiphol Group (RSG), this research provides valuable insights into the future of airside operations. First of all, the research challenges Schiphol's strategic roadmap for achieving fully autonomous airside operations by 2050. The study highlights that fully autonomous operations without human operator interaction is not feasible. It shows that human operators are necessary for a successful implementation of an autonomous bus system.

Additionally, the study contributes to the enhancement of the safety proposition of RSG. In Schiphol Airport, ensuring safety and reliability in the operation of autonomous buses is the main priority. The research's findings on the different human operator roles and the procedures during boarding, commute, and deboarding contribute to developing robust protocols that enhance the safety of autonomous bus system.

Furthermore, the study's findings support RSG in making informed decisions about automation implementation. The future scenarios that are presented, serve as a discussion starter for RSG, to discuss contextual implications that need to be overcome before implementation. Additionally, it addresses potential challenges related to passenger trust and potential scenarios in case of an emergency. RSG could take these research findings into account to stimulate the succesful implementation of an autonomous bus system.

Lastly, the research shows how to successfully integrate a human-centered design approach in new product or service development of the company. The study highlighted empathizing with the operational-level employees, in this case human operators, to get an in-depth understanding of the current operations, to identify their perceptions, beliefs, and needs, and to keep them in the loop when designing future innovations, to stimulate successful implementation by human operators. This approach could be further explored by integrating the methodology into future innovation projects.

8.3 Generalizability

The findings of this study are particularly relevant for other high-traffic and regulated multi-stakeholder environments where safety has high priority, such as other airports, seaports, and closed business parks. The roles and responsibilities identified can serve as a model for similar settings, where human operators must work alongside autonomous systems.

However, RSG is quite an innovative organization when it comes to autonomous vehicles. Therefore, other less-developed organizations could struggle with applying the study insights in their operational context. Despite the level of autonomous vehicle development in organizations, the study could be used as a peek into future possibilities and could stimulate discussion on future human roles in autonomous environments.

Additionally, the methodological approach using human-centered design to empathize with the current manual bus operation, combining literature review, context study, and expert interviews, can be applied to other sectors to understand the future roles of human operators in different automated environments.

8.4 Limitations

Despite the comprehensive approach, this study has several limitations:

First, since the project had to be completed within 100 days, time was a limited factor in this study. Especially the arrangement for the shadow sessions with employees from RSG, sampling of participants for the expert interviews, and planning the interviews took more time than expected, leading to limited participants, shadow shifts, and interviews.

Consequently, a small number of participants was studied during shadow shifts in the context research (i.e., 3 human operators). A larger number of participants might have created a wider variety of outcomes, a deeper understanding of the current manual bus operations, and insights into more specific scenarios where human operators are crucial besides their driving role.

Moreover, the study primarily relied on expert interviews, which, while informative, may introduce biases based on the experts' perspectives and experiences. All participants in the expert interviews were male, which may indicate a potential bias. Future research could benefit from a more diverse range of stakeholders, including more on-site human operators, flight attendants, and passengers, to provide a more holistic view of the impact of automation on the bus operation.

Additionally, bias from the main researcher needs to be acknowledged during the expert interviews. The main researchers positionality, by making the assumption that human operators remain essential in an automated system, might have led to giving directions towards potential future scenarios and influencing participant's answers. Furthermore, by presenting a simplified version of the Social Network Analysis map, which shows the current human operator roles and their interactions with each other, the researcher might have limited participants' creative freedom when envisioning potential future human roles and scenarios.

In addition, it is crucial to acknowledge the bias of the main researcher during the data analysis process. Despite deciding to follow a reflexive thematic analysis approach (Braun & Clarke, 2013), subjectivity in the data analysis was inevitable. By iterative reflection during the process, where the main researcher reflected on preconceptions about the subject and about the researcher's positioning, bias was minimized. In future research, the data analysis could be conducted by multiple researchers, to reduce one's individual bias.

Furthermore, the speculative design methodology has its limitations. Speculative design is an innovative method to envision and explore possible futures. However, it relies on assumptions and projections, created by the main researcher, that may not fully capture future realities. During the expert interviews, different assumptions were made by experts about the technological capabilities of the autonomous bus system, which served as a foundation for the final concept scenarios. This resulted in future scenarios that might not completely represent future realities.

Lastly, the research was conducted within the specific context of Schiphol Airport, which may limit the generalizability of the findings to other airports or other controlled and highly regulated environments. The generated concepts might be difficult to apply to other settings. However, the applied method combination, using a human-centered design approach by creating a speculative design artifact based on in-depth literature research and context research (i.e., shadow sessions and expert interviews), could be generalized in further research.

8.5 Future work

Following the human-centered design methodology (Figure 1), the next step in this study is to test the prototype. This could be done by conducting an evaluation study in focus groups with stakeholders from different departments within RSG to validate the final concept. The speculative design artifacts could be used as a prompt to generate a rich discussion on the future human operator roles in an autonomous bus system and make the concept more tailored to the context of Schiphol Airport. The desired outcome of the evaluation study would be to identify contextual implications to consider before implementing future human operator roles in an autonomous bus system in airside operations. Appendix E shows an approach for the evaluation sessions.

Additionally, studies could provide insights into contextual implications of human operators in autonomous bus systems in other airports and other high-traffic and regulated multi-stakeholder environments, such as seaports or closed business parks. Validating these findings in other contexts and settings could make the insights of future human operator roles in autonomous bus systems in controlled environments more generalizable.

This research has been an exploratory study towards using human-centered design principles to design future human operator roles in an automated workplace. Future work could further explore the use of human-centered design to broaden the understanding of human roles in other automated environments and to design supportive human-automation interaction frameworks.

Moreover, longitudinal studies could provide insights into how these human roles evolve over time and into the long-term impacts of the redesigned roles on human operator satisfaction and performance.

Lastly, there is a need to explore the development and implementation of training programs designed to equip human operators with the skills necessary to work alongside automated systems. During the experts interviews, experts highlighted the necessity to provide additional training to human operators in the current bus operation. The role of the bus driver, bus coordinator, and bus director could evolve into remote driver, supervisor, or rescuer. Additionally, the role of the safety driver has the potential to evolve into the host, hostess, fleet coordinator, or (de)boarding assistant. Therefore, training programs need to be designed.

Conclusion

This master thesis explored what the potential future roles of human operators are in an autonomous bus system in Autonomous Airside Operations, focusing on the boarding and deboarding procedure at bus gates at Schiphol Airport.

The successful integration of technology relies not only on its technical capabilities but also on human operators, who will work in and interact with an autonomous bus system. By placing humans at the center of the design process, a valuable future human operator role can be created, that participates in the successful implementation of an autonomous bus system in Autonomous Airside Operations. Therefore, a human-centered design approach is followed (Zijlstra et al., 2014), consisting of the following steps: (1) emphathized with the current bus operations by conducting a literature study, context study in the form of shadow shifts with human operators, and in-depth expert interviews; (2) defined the design challenge after synthesizing the literature, context, and expert interview insights, which is as follows:

The challenge is to design future roles for human operators that address scenarios where human intervention is required in an autonomous bus system during the boarding and deboarding procedure at bus gates in Autonomous Airside Operations.

(3) ideated several future scenarios and potential roles and combined them in a final design; and (4) created a prototype in the form of animation videos, which serves as a speculative design artifact for future discussion.

The context research revealed four current operator responsibilities besides driving-related tasks. Additionally, based on the expert interviews, five future human operator responsibilities in Autonomous Airside Operations are identified. Combinations between current and responsibilities resulted in the design of four potential future scenarios, each with a different future human operator role.

The study provides four human operator roles in potential future scenarios where human operators remain crucial in an autonomous bus system, which is: (1) the role of the safety driver to enable autonomous driving as an addition to manual operations; (2) the role of host/hostess or fleet coordinator to provide on-board assistance; (3) the role of the (de)boarding assistant to ensure a safe boarding and deboarding procedure; and (4) the role of the rescuer to immediately operate in case of an emergency. Animation videos are made based on these scenarios, which serve as speculative design artifacts.

The study provides a context-specific tangible example of human-centered work design. However, more research is needed to test and evaluate the speculative design artifacts on feasibility, viability, and desirability and to identify contextual implications that need to be overcome before implementing an autonomous bus system in airside operations in the context of Schiphol Airport.

Ultimately, this study aims to integrate human-centered design principles in technological-driven innovation initiatives and can hopefully provide inspiration for future innovators and organizations.

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Appendix

A. Informed consent form

TEMPLATE 2: Explicit Consent points

PLEASE TICK THE APPROPRIATE BOXES	Yes	No
A: GENERAL AGREEMENT – RESEARCH GOALS, PARTICPANT TASKS AND VOLUNTARY PARTICIPATION		
1. I have read and understood the study information dated 22-01-2024, or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	☐	☐
2. I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason without any further consequences in my job or work environment.	☐	☐
3. I understand that taking part in the study involves an audio-recorded interview, where the audio will be transcribed as text and anonymized for further analysis. The audio will be deleted after the completion of the study.	☐	☐
5. I understand that the study will be a one-time interview, which could have a duration from 30 to 60 minutes.	☐	☐
B: POTENTIAL RISKS OF PARTICIPATING (INCLUDING DATA PROTECTION)		
6. I understand that taking part in the study involves the following risks, due that it is conducted within an organisation: 1) participants might feel the obligation to participate; 2) answers could potentially reveal commercially confidential information; 3) participants might feel hindered in expressing their opinion. I understand that these will be mitigated by keeping participants' identity anonymous, by carrying a confidentiality check before the study is published, and by allowing participants to withdraw at any time.	☐	☐
7. I understand that taking part in the study also involves collecting specific personally identifiable information (i.e. name, email, and department name) and associated personally identifiable research data (i.e. description of current role) with the potential risk of my identity being revealed or my image being damaged.	☐	☐
9. I understand that the following steps will be taken to minimise the threat of a data breach, and protect my identity in the event of such a breach: transcription of the voice recording to anonymized text, destruction of the recordings, secure data storage with no access to the organization, and confidentiality on the identity and department of the participants.	☐	☐
10. I understand that personal information collected about me that can identify me, such as name, email or department, will not be shared beyond the study team.	☐	☐
11. I understand that the (identifiable) personal data I provide will be destroyed after the Master thesis is completed (in July 2024).	☐	☐
C: RESEARCH PUBLICATION, DISSEMINATION AND APPLICATION		
12. I understand that after the research study the de-identified information I provide will be used for published Master thesis.	☐	☐
13. I agree that my responses, views or other input can be quoted anonymously in research outputs.	☐	☐

Signatures

________________________ ________________________ ________
Name of participant [printed] Signature Date

I, as researcher, have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

Femke van Dam ________________ 22-01-2024
Researcher name [printed] Signature Date

Study contact details for further information: Femke van dam, f.l.vandam@student.tudelft.nl, 0621339727

B. Interview guide

EXPERT INTERVIEW GUIDE

Research questions:

RQ1: What are different perspectives on the future human operator role and how does this differ from the current role?
RQ2: Where and how would human operators intervene in a future autonomous bus system in airside operations?

Checklist for start
- Informed consent form
- Audio-record equipment (Dictaphone tool)
- Laptop with internet connection
- Microsoft Teams
- Whisper AI for transcription
- Movie clip (sensitizing material)
- Notebook and pen
- Quiet reserved space

Introductory script

Hey, thank you for making the time for this interview. *How are you doing?*
Let me introduce myself. I am Femke van Dam, a Strategic product design student at the TU Delft. I am currently doing a graduation project in collaboration with Royal Schiphol Group.
Could you tell me something about yourself?

This interview aims to understand the different perspectives on the future role of the human operator and to explore where human operators intervene in an autonomous bus system. The interview is strictly confidential, and you can withdraw from the interview at any point in time. There are no right or wrong answers, I am interested in your opinions and personal experiences. Feel free to interrupt at any time. I would like to record this interview to transcribe it later. Are you okay with this?

Let me first explain Schiphol's future vision and the team I am working with. Schiphol aims to become the world's most sustainable and high-quality airport by 2050. Therefore, Schiphol has initiated the Autonomous Airside Operations team, which aims to make all vehicles and processes on the airside sustainable and autonomous.

I am doing research on autonomous buses in the context of airside operations at airports. First, I would like to start with some initial questions about your experience with an autonomous bus system and your perspective on the future role of human operators in an autonomous bus system. After that, I would like to show you the current bus system and the way of working from a human operator perspective. I would like to further understand how and where you think human operators will intervene in a future autonomous bus system in airside operations.

Part 1: Capturing different perspectives.

Interview questions:
- What is your experience with autonomous buses and/or transportation systems?
- What roles do you see the human operator play in an autonomous bus system?
- How might this differ from current operations?

Part 2: Sensitizing with the context
Next, I will present the current bus operations at airside, to get a better view of the airport context and to understand which human operators play a part in the current bus system. I will do this by first, presenting you a video collection of the different human operators during their work shifts. After that, I will present a map of the current bus system.

Interview questions:

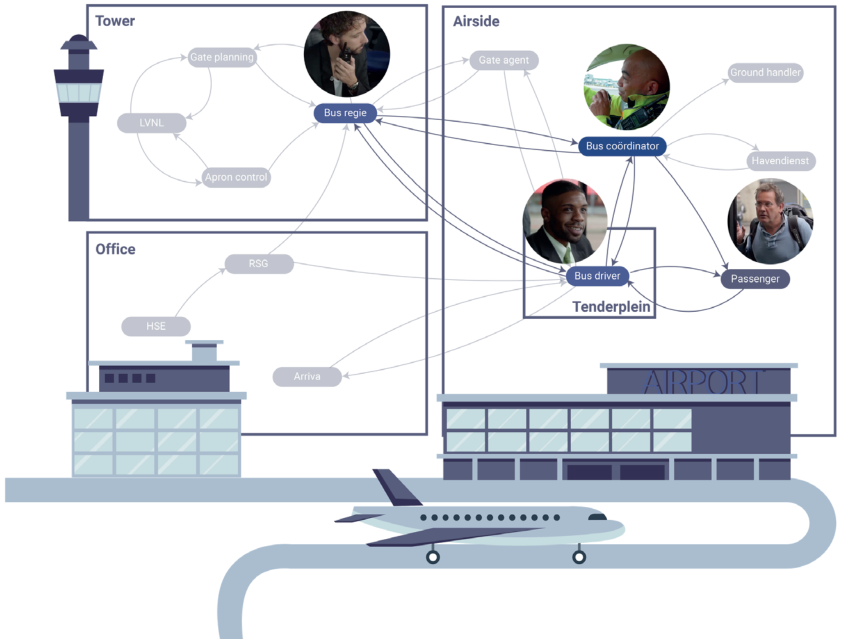
- What is your first reaction to the current bus system?
- What opportunities do you foresee in the implementation of an autonomous bus system in this context?
- What challenges do you foresee?
- Will an autonomous bus system impact the role of these human operators? If yes, in what way?

Follow-up questions:

- What surprised you?
- Would it be extra difficult to implement an autonomous bus system in this context? Why?

Map of the current bus system:

Current bus system at Schiphol Airport



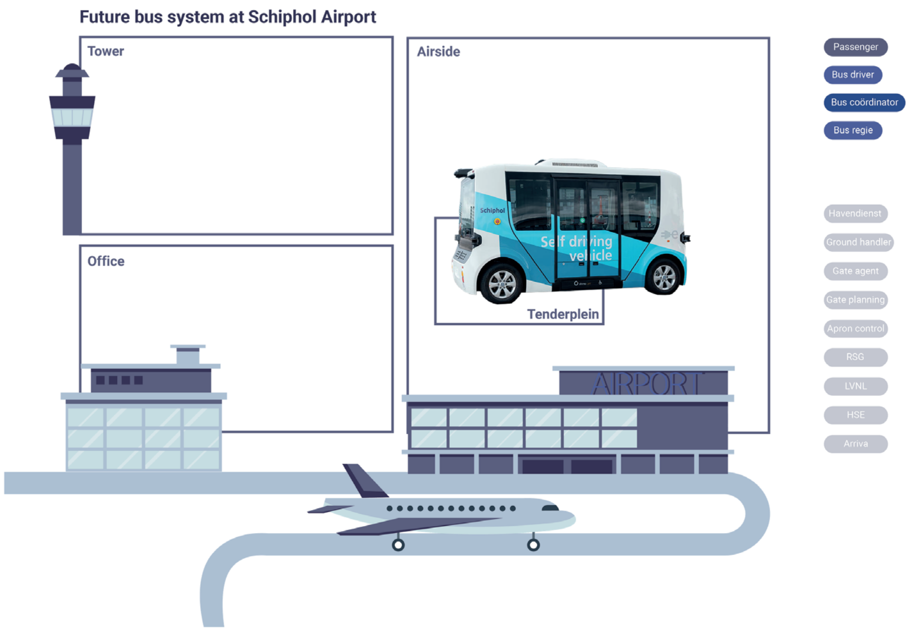
Part 3: Envisioning a future autonomous bus system

I would like to further elaborate on how you envision the interaction between human operators and autonomous buses. Therefore, I would like to create a similar system to the one I presented earlier.

Interview questions:
- Who is responsible for operating the autonomous bus system?
- What would be the tasks of the autonomous bus?
- What would be the tasks of the human operator?
- Which human operators are involved in the autonomous bus system?
- What are the touch points where human operators intervene with the autonomous bus system?
- What if the autonomous bus gives an error?
- How could Schiphol provide assistance to passengers?

Follow-up questions:
- Will there be a human operator present in the bus or not?
- How could human operators communicate with the autonomous buses?
- And with other human operators?
- Is there a new role needed?

During this section, the following template will be filled in with the participant on Miro or paper:



Checklist for closure

- Give a summary of the future bus system and the role of the human operator
- Ask the participant if he/she has a last comment
- Ask the participant if he/she has remaining questions
- Ask the participant if it is okay to refer back to him/her to clarify something
- Thanking the interviewee

List of probes

- Simplified visual of the current bus system
- Video compilation of human operators working in the current bus system at airside
- Template for future autonomous bus system

EXPERT INTERVIEW GUIDE - DUTCH

Onderzoeksvragen:
RQ1: Wat zijn verschillende perspectieven op de toekomstige rol van de menselijke operator en hoe verschilt dit van de huidige rol?
RQ2: Waar en hoe zouden menselijke operators ingrijpen in een toekomstig autonoom bussysteem in de airside?

Checklist voor start:
- Toestemmingsformulier
- Audio-opnameapparatuur (Dictafoontool)
- Laptop met internetverbinding
- Microsoft Teams
- Whisper AI voor transcriptie
- Filmpje (sensibiliseringsmateriaal)
- Notitieboekje en pen
- Stille gereserveerde ruimte

Introductiescript:
Hallo, bedankt dat je tijd maakt voor dit interview. Hoe gaat het met je?
Laat me mezelf voorstellen. Ik ben Femke van Dam, een student Strategic Product Design aan de TU Delft. Ik werk momenteel aan mijn afstudeerproject in samenwerking met de Royal Schiphol Group.
Kun je iets over jezelf vertellen?

Dit interview heeft het doel om de verschillende perspectieven op de toekomstige rol van de menselijke operator te begrijpen en te onderzoeken waar menselijke operators zouden ingrijpen in een autonoom bussysteem. Het interview is strikt vertrouwelijk en je kunt op elk moment besluiten om niet verder te gaan. Er zijn geen goede of foute antwoorden, ik ben geïnteresseerd in je mening en persoonlijke ervaringen. Onderbreek gerust wanneer je maar wilt. Ik wil dit interview opnemen om het later te transcriberen. Is dat goed voor jou?

Laten we eerst Schiphols toekomstvisie en het team waarmee ik werk uitleggen. Schiphol streeft ernaar om tegen 2050 's werelds meest duurzame en hoogwaardige luchthaven te worden. Daarom heeft Schiphol het team Autonomous Airside Operations opgericht, dat tot doel heeft alle voertuigen en processen aan de luchtzijde duurzaam en autonoom te maken.

Ik doe onderzoek naar autonome bussen in de context van Airside operations op luchthavens. Eerst wil ik beginnen met enkele initiële vragen over je ervaring met een autonoom bussysteem en je perspectief op de toekomstige rol van menselijke operators in een autonoom bussysteem. Daarna wil ik je het huidige bussysteem en de werkwijze vanuit het perspectief van een menselijke operator laten zien. Ik wil graag begrijpen hoe en waar jij denkt dat menselijke operators zullen ingrijpen in een toekomstig autonoom bussysteem in de luchtvaartsector.

<u>Deel 1: Verschillende perspectieven vastleggen.</u>
Interviewvragen:

- Wat is jouw ervaring met autonome bus en/of transport systemen?
- Welke rollen zie je voor de menselijke operator in een autonoom bussysteem?
- Hoe kan dit verschillen van de huidige operaties?

<u>Deel 2: Sensibiliseren met de context.</u>
Vervolgens zal ik de huidige bussystemen aan de airside presenteren, om een beter beeld te krijgen van de luchthavencontext en om te begrijpen welke menselijke operators een rol spelen in het huidige bussysteem. Dit zal ik doen door eerst een videocollectie te tonen van de verschillende menselijke operators tijdens hun diensten. Daarna zal ik een kaart van het huidige bussysteem presenteren.

Interviewvragen:

- Wat is jouw eerste reactie op het huidige bussysteem?
- Welke kansen zie je voor de implementatie van een autonoom bussysteem in deze context?
- Welke uitdagingen voorzie je?
- Zal een autonoom bussysteem de rol van deze menselijke operators beïnvloeden? Zo ja, op welke manier?

Follow-upvragen:
- Wat verraste je?
- Zou het extra moeilijk zijn om een autonoom bussysteem in deze context te implementeren? Waarom

<u>Deel 3: Een toekomstig autonoom bussysteem visualiseren.</u>
Ik wil graag verder ingaan op hoe jij je de interactie tussen menselijke operators en autonome bussen voorstelt. Daarom wil ik een vergelijkbaar systeem creëren als het systeem dat ik eerder heb gepresenteerd.

Interviewvragen:

- Wie is verantwoordelijk voor het bedienen van het autonome bussysteem?
- Wat zouden de taken van de autonome bus zijn?
- Wat zouden de taken van de menselijke operator zijn?
- Welke menselijke operators zijn betrokken bij het autonome bussysteem?
- Wat zijn de contactpunten waar menselijke operators ingrijpen in het autonome bussysteem?
- Wat als de autonome bus een fout geeft?
- Hoe kan Schiphol assistentie bieden aan passagiers?

Follow-upvragen:
- Zal er een menselijke operator aanwezig zijn in de bus of niet?
- Hoe kunnen menselijke operators communiceren met de autonome bussen?
- En met andere menselijke operators?
- Is er een nieuwe rol nodig?

Checklist voor afsluiting:

- Geef een samenvatting van het toekomstige bussysteem en de rol van de menselijke operator.
- Vraag de deelnemer of hij/zij nog een laatste opmerking heeft.
- Vraag de deelnemer of hij/zij nog vragen heeft.
- Vraag de deelnemer of het goed is om hem/haar te raadplegen voor verduidelijking.
- Bedank de geïnterviewde.

Lijst van hulpmiddelen:

- Vereenvoudigde visuele weergave van het huidige bussysteem
- Videocompilatie van menselijke operators die werken in het huidige bussysteem aan de luchtzijde
- Sjabloon voor toekomstig autonoom bussysteem

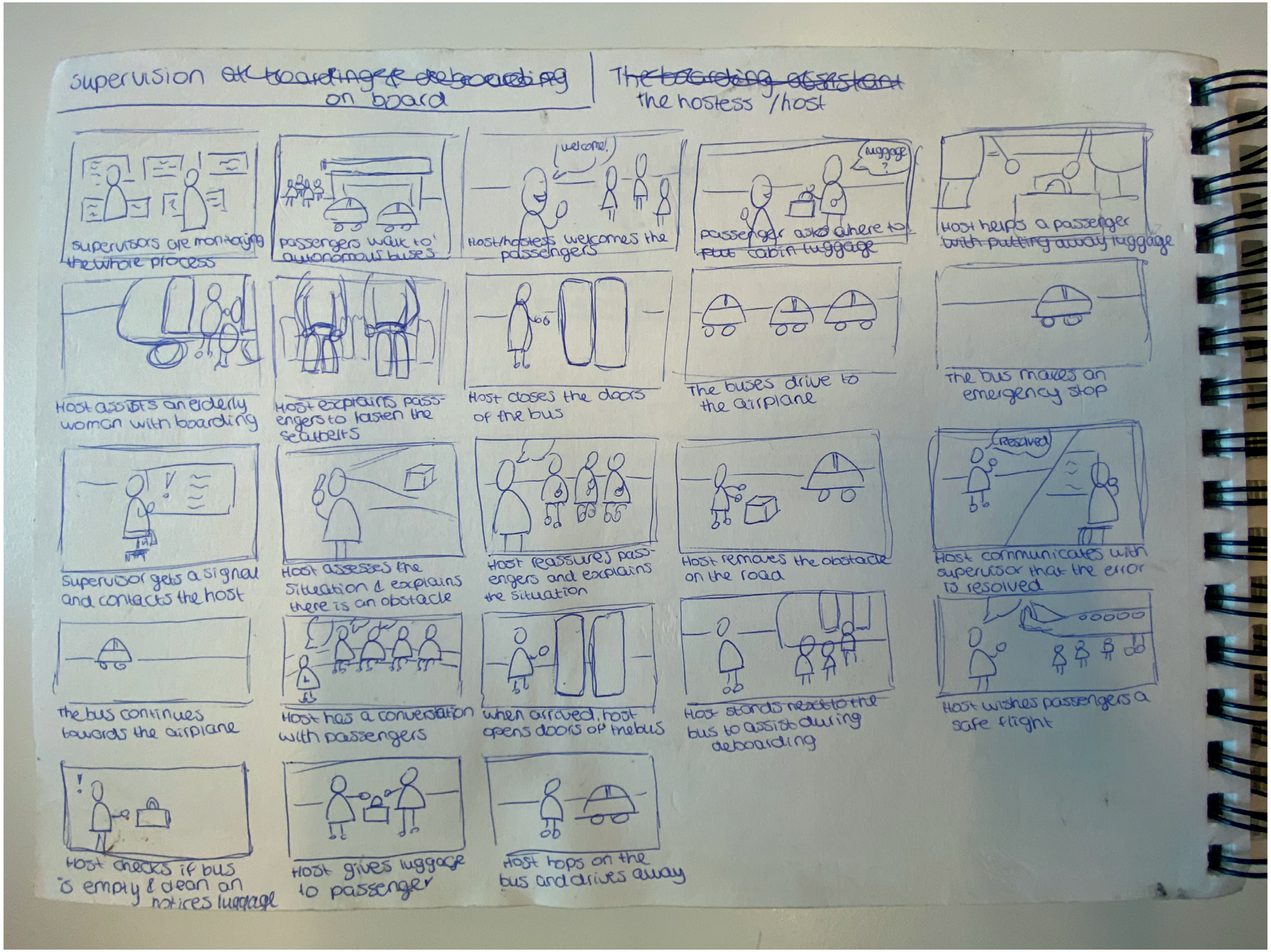
C. Overview of current and potential future human operator tasks, besides the driving-related tasks

Remaining human operator tasks based on conctext research	Additional future human operator tasks based on expert interviews
Control passenger behavior	Monitor alerts
Open & close the doors of the buses	Assess the situation
Check forgotten luggage	Resolve small malfunctions
Assist passengers with luggage	Let passengers put on seat belts
Watch the cameras	Send buses with big malfunction to depot
Communication with passengers	Send back up buses
Check if the buses are empty	Give boarding instructions
Ensure safety on board	Manual takeover
Communication with other human operators	Conduct software updates
Check if the buses are clean	Daily bus system check
Assist during boarding and deboarding	Resolve big malfunctions
Keep the buses clean	Educate passengers
Makes passengers feel at ease	
Prevent passengers from moving freely	
Answer questions from passengers	

Overview of remaining tasks of current human operators (based on context research) and additional future tasks in an autonomous bus system (based on expert interviews)

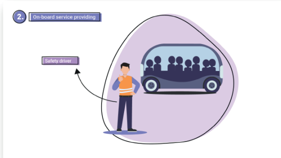
D. Iterations for the final storyboard designs

Sketch for the storyboard of the host/hostess

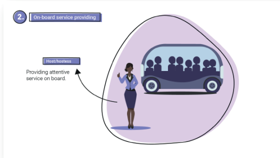


First design for the storyboard of the host/hostess

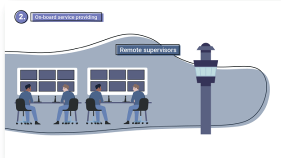
Intro.



As the autonomous bus system advances, a safety driver will no longer be necessary.



To ensure a user-friendly experience and build passenger trust, phase two introduces an on-board service: the host or hostess.



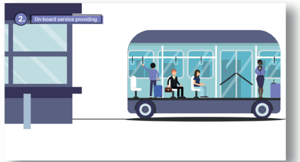
In this scenario, supervisors monitor bus operations from a remote location.

The host or hostess welcomes passengers as they walk from the terminal to the autonomous buses.

The host or hostess takes on responsibilities such as answering passenger questions.

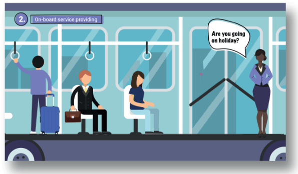
and assisting passengers with their luggage.

After all passengers have boarded the bus, the host or hostess accompanies the bus and closes the doors.

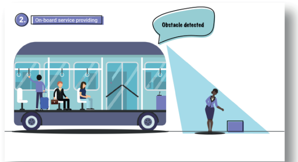


the buses then drive to the airplane.

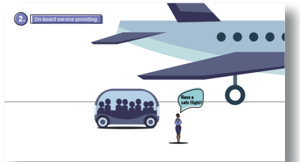
During the commute, the host or hostess educates passengers about autonomous technology.



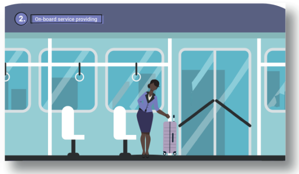
or engages with them about their upcoming trip.



In case of issues, the host or hostess assesses the situation, resolves minor malfunctions if possible, communicates with the bus director, and continues the route.

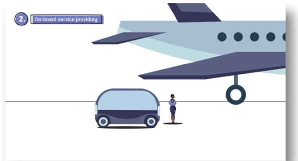


Upon arrival at the airplane, the host or hostess stands besides the bus and wishes passengers a safe flight..

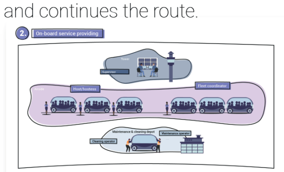


After the last passenger departs the bus, the host or hostess inspects all the buses to ensure they are empty and clean. If the host or hostess finds forgotten luggage on one of the buses,they give it to the cabin crew to return to the passenger.

If the host or hostess notices a spill in the bus, they call the supervisor to send the bus to the maintenance depot and request a back-up bus..



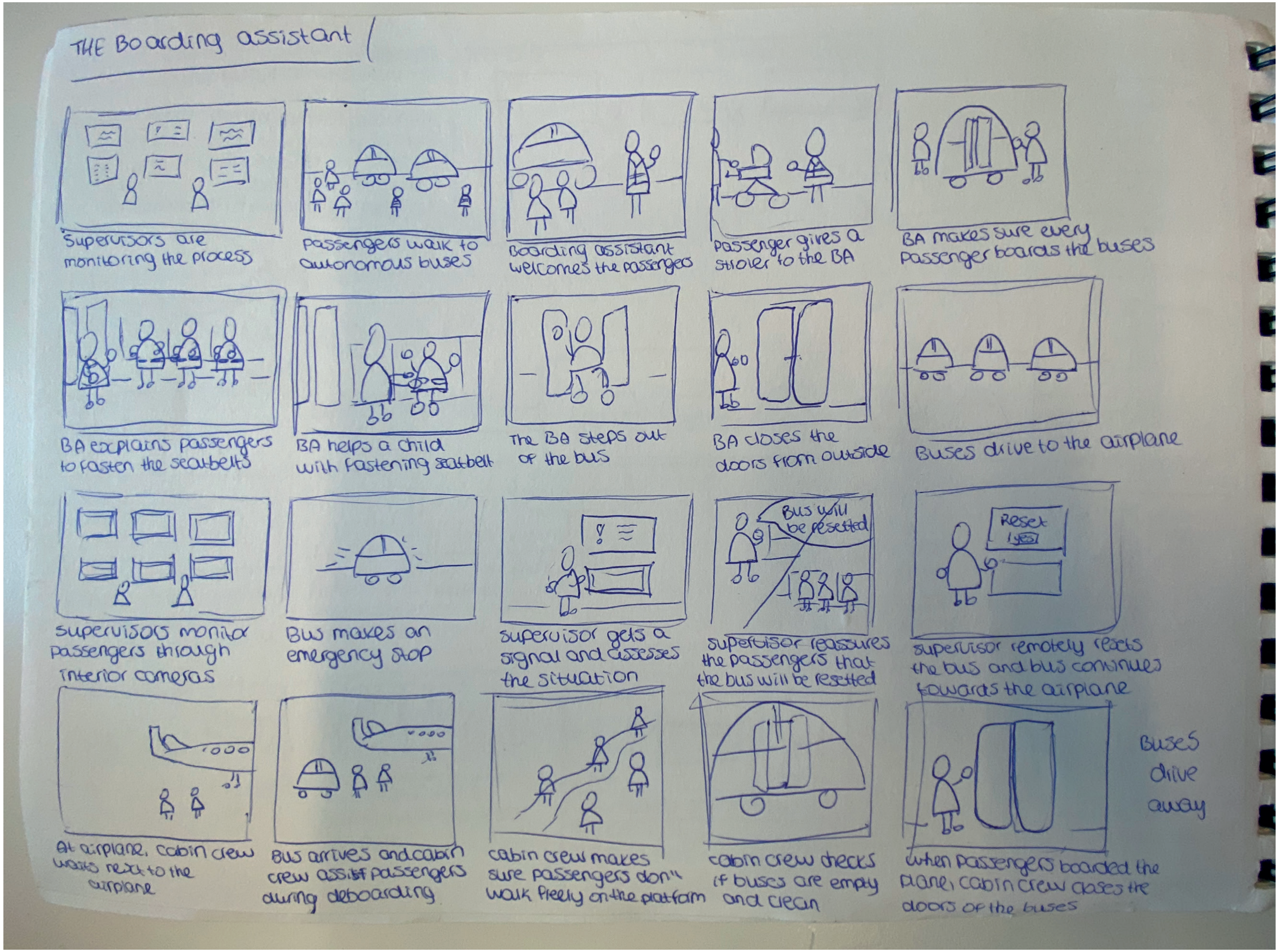
Afterward, the host or hostess rejoins the bus for the next task.



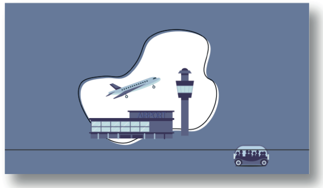
As passenger trust in the system grows, this role can be gradually scaled back to one host or hostess per fleet, acting as the fleet coordinator. The fleet coordinator will have the same responsibilities but will accompany the first and last buses in the fleet instead of having one operator per bus.

Outro.

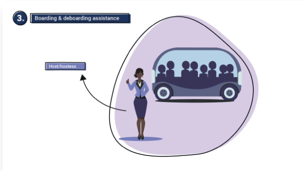
Sketch for the storyboard of the boarding assistant



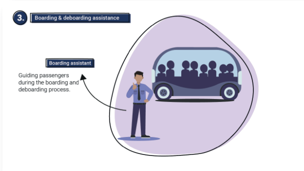
First design for the storyboard of the boarding assistant



Intro.



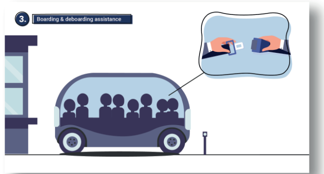
Instead of having a human operator accompany the buses, another option is to station them at fixed positions for boarding and deboarding.



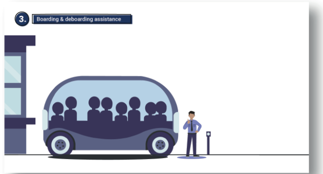
This scenario introduces the role of the boarding assistant, who will guide passengers during the boarding and deboarding process.

As passengers walk from the terminal to the autonomous buses, the boarding assistants welcome them.

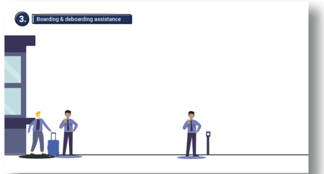
One boarding assistant helps an older woman with her luggage,



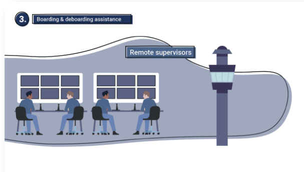
while another provides clear seat belt instructions.



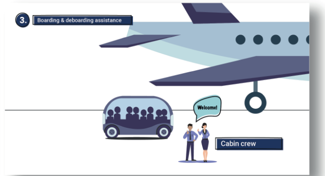
The boarding assistant checks if the bus is ready to depart, steps out, closes the doors, and sends the bus toward the airplane.



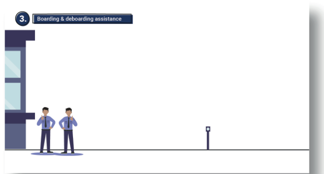
Another boarding assistant holds back passengers until the next bus arrives.



During transit, supervisors monitor the bus using interior cameras and a two-way intercom to communicate with passengers if necessary.



When the buses arrive at the airplane, the cabin crew oversees the deboarding procedure.



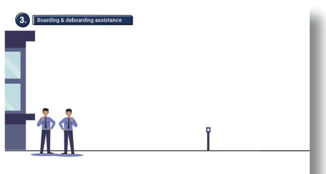
Meanwhile, the boarding assistants wait for the next arriving flight.

When the buses arrive, the boarding assistants ensure a safe and comfortable deboarding.

One boarding assistant brings a stroller to a passenger with a child.

After that, the assistant checks if the buses are empty, clean, and free of forgotten luggage.

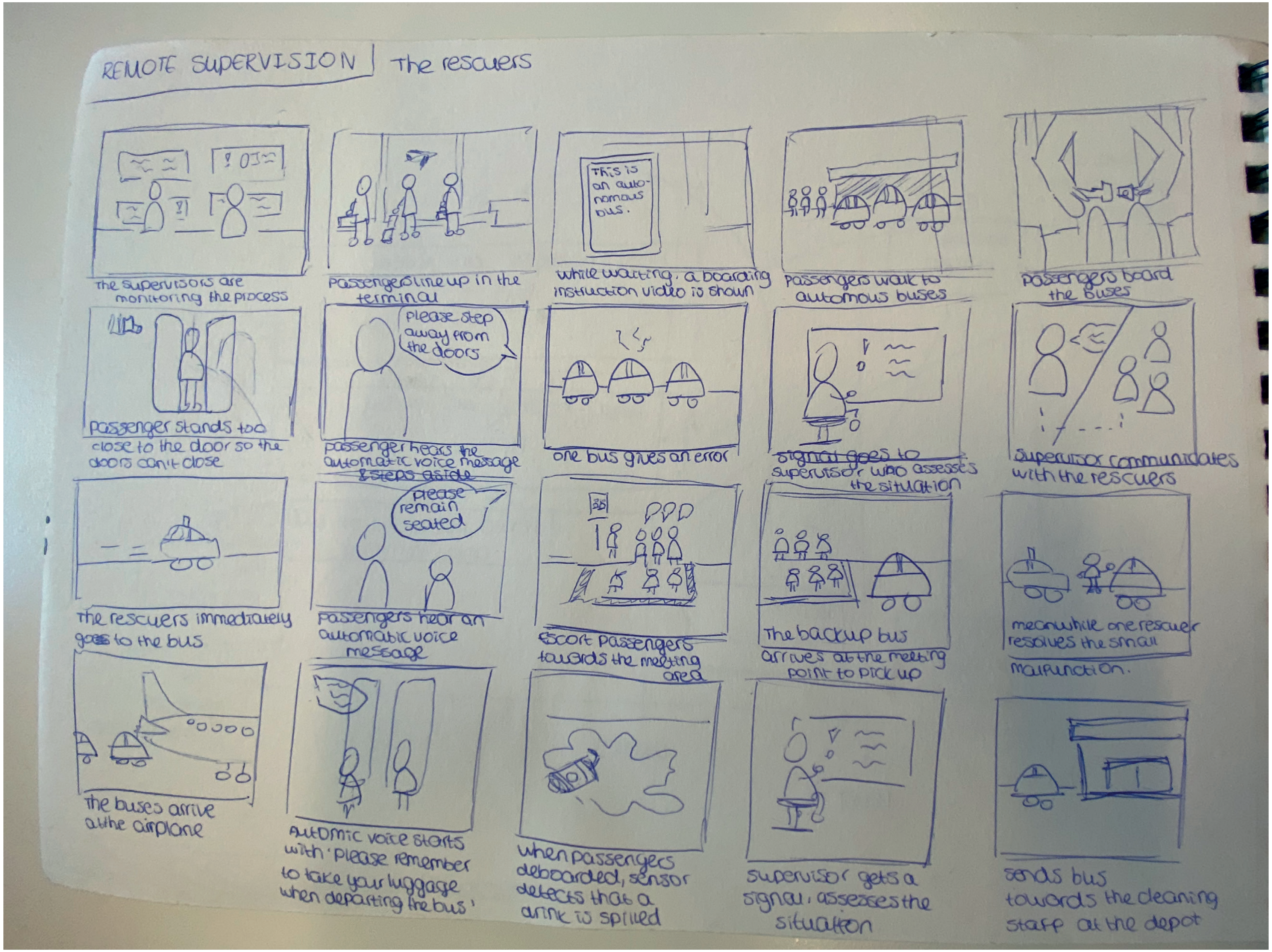
Another boarding assistant checks if all passengers have entered the terminal and asks any remaining passengers to follow the others inside.



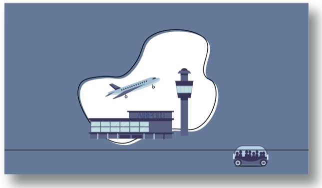
After the deboarding procedure is completed, the boarding assistants wait for the next departing flight.

Outro.

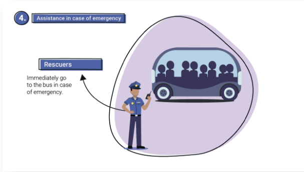
Sketch for the storyboard of the rescuer



First design for the storyboard of the rescuer



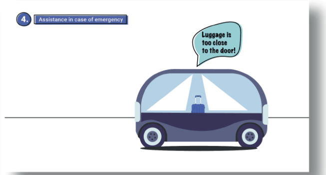
Intro.



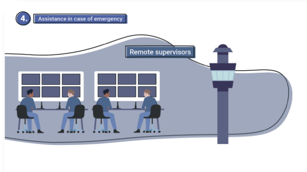
In this scenario, human operators remain essential as backup process in case of an emergency.

Passengers line up in the terminal. While waiting, a boarding instruction video is presented.

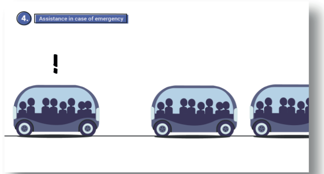
The passengers walk outside of the terminal and board the autonomous buses.



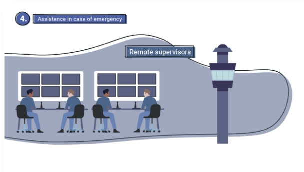
Interior sensors will detect if passengers have not fastened their seat belts or if luggage is too close to the door.



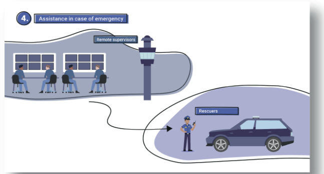
After the buses depart, the passengers in the bus will be monitored by the remote drivers or supervisors, with the help of sensors and interior cameras.



During transit, one of the buses makes and emergency stop.

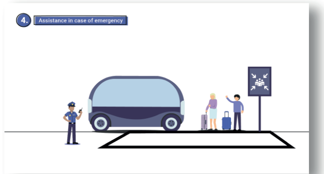


Remote drivers or supervisors will receive notification-based alerts and assess the situation.

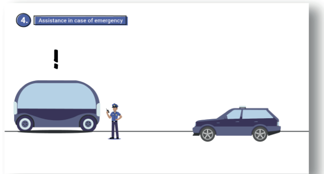


They coordinate immediately with the rescuer and the rescuers attend the scene with high priority.

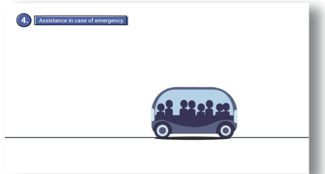
Meanwhile, passengers are reassured by the remote supervisor via the intercom that help is on the way.



Upon arrival, the rescuers support passengers and escort them to a designated meeting area. A backup bus is dispatched by the supervisors.

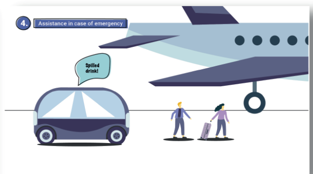


Meanwhile, one rescuer tries to resolve a small malfunction on-site. If it cannot be resolved, the bus is sent to the maintenance depot.

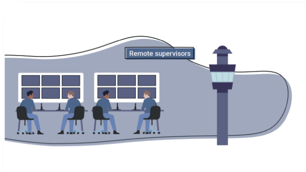


The backup bus arrives and the bus continues toward the airplane

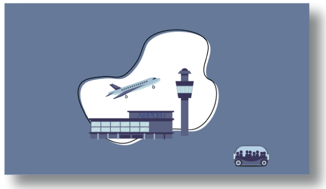
Upon arrival, passengers receive deboarding instructions from the automated voice assistant.



When passengers are deboarded, sensors detect a spilled drink.



The supervisors get a signal, assesses the situation, and sends the bus towards the cleaning staff at the depot.



Outro.

E. Evaluation study approach

Evaluation study aims

The aim of the research is to generate a rich discussion on the future of work by evaluating the concept of the future human operator roles in an autonomous bus system and to make the concept more tailored to the context of Schiphol Airport. The desired outcome of the study is to identify contextual implications to consider about the future human operator roles before implementing an autonomous bus system in airside operations at Schiphol Airport. The evaluation study is conducted two answer the following research question:

RQ5: What are the contextual implications to consider to successfully implement future human operator roles in an autonomous bus system in the context of Schiphol Airport?

Method

Study design

The study consists of two focus group discussions. According to Braun & Clarke (2013), a focus group is a group discussion 'focused' on a particular topic or theme - in this instance, the future human operator role in an autonomous bus system in Schiphol airside operations. A focus group is used, since it is suitable for gathering different perspectives, evokes discussion about the topic, brings new knowledge, and creates consciousness among participants, which potentially fosters change in the organisation (Braun & Clarke, 2013). Since the evaluation study serves as an exploratory conversation with different stakeholders within RSG, a focus group is an appropriate method to engage participants in a rich discussion and to gather different perspectives from different departments within the organisation.

The purpose of the focus group is to evaluate the future human operator role in an autonomous bus system in the context of Schiphol airside operations and to detail the contextual implications for the organisation that we need to consider before implementation. The final design is used as prompt to start the conversation. to evaluate the concept, the design is examined based on the following questions:

- Can the design reveal different perspectives of participants on the future human operator roles in an autonomous bus system?
- Does the design help the organization identify contextual implications that we need to overcome before implementing future human operator roles in an autonomous bus system at Schiphol Airport?
- Are the scenarios feasible in the context of Schiphol Airport?
- Are the scenarios desirable in the context of Schiphol Airport?

The outcome of the focus group discussion include a detailed overview of contextual implications. Based on the focus group insights, further recommendations are proposed for the successful implementation of future human operator roles in an autonomous bus system at Schiphol Airport.

Pilot test

Pilot test is planned with different colleagues from the Innovation Hub. The aim of the pilot thest is to update the focus group guide with realistic time frames and additional questions.

Participants and sampling

Recommendations for focus group size vary (Krueger and Casey, 2009; Morgan, 1996). Braun & Klarke (2013) recommended to rather have a smaller group with 3-8 participants, to generate a rich discussion and to keep the discussion manageable. Therefore, two evaluation sessions were conducted, each involving four participants. Initially, Participants are sampled through purposeful sampling, to ensure the diverse group dynamic consisting of participants from various departments.
This is done because research suggests the necessity to have enough diversity in the focus group to ensure an interesting discussion (Barbour, 2005). Therefore, the participants are sampled from different departments within the organisation of RSG: (1) human resources; (2) current bus operations; (3) Safety; and (4) program development. The participants are both management-level and operator-level employees to stimulate . An overview of the participants and their roles within RSG is presented in Table 2.

Except for Participant 4 (P4), none of the participants have been involved in the research so far, to minimize bias. P4 took part in the expert interviews and therefore had an impact on the final concept, introducing some bias. Nevertheless, due to P4’s essential role in the current and future bus system, their involvement is necessary to receive valuable contextual implications. The participants must remain anonymous since it allows the participants to speak freely about their opinions.

Tools and procedure

Tools

- Informed Consent forms
- Slide with the introduction of the session
- 3 animation videos, 1 of each scenario
- Printed job description cards
- 3 printed storyboards, 1 of each scenario
- 3 printed reflection sheets, one of each scenario
- Post-its and markers

Procedure

After sampling and inviting participants for face-to-face appointments, a suitable time and location were arranged for the focus group sessions, and a semi-structured focus group guide was developed. The main researcher acted as the moderator, assisted by an employee from the Innovation Hub, who served as the assistant moderator. We acknowledged the fact that this employee of RSG can cause internal pressure among the participants towards certain answers, and could create biases. Therefore, the moderator assistant only assisted with preparing the room, placing the materials, taking photographs, writing down key insights, and did not participate the discussion. Each discussion lasted for one hour.

The session began with the moderator asking participants to introduce themselves. Following the introductions, the moderator provided a brief overview of the research, explaining the session's purpose, structure, and discussion rules, emphasizing the anonymity of the outcomes and participants' right to withdraw at any time. Participants received and signed informed consent forms.

The moderator then explained the first phase, which involved scenarios where autonomous buses would supplement manual operations, including the role of the safety driver. This was followed by an explanation of phase two, which focused on scenarios where human operators remained essential. An animation video of the first scenario (Chapter 7) was presented, illustrating future human roles in an autonomous bus system. The assistant moderator then placed storyboards and job descriptions of the human operator roles on the table. The moderator invited initial questions based on the video and provided further explanations as needed.

After addressing initial questions, the discussion started. The moderator guided the discussion using the focus group guide with the following semi-structured questions:

- What are your initial thoughts on the proposed roles of human operators in this autonomous bus system?
- Do you think this scenario with this human operator role is desirable for RSG? Why/why not?
- What would be the effect of this scenario on the current operations of Schiphol Airport?
- What specific factors related to Schiphol Airport's operations need to be considered when implementing this concept?

During the discussion, the assistant moderator wrote down key insights on a reflection sheet. This procedure was repeated for scenarios two and three.

The session concluded with the assistant moderator summarizing the insights from the reflection sheet. The main moderator then invited participants to share any additional thoughts or views and asked about their experience participating in the focus group. The session ended with the moderator thanking the participants and giving them chocolate bars as a token of appreciation.

Data analysis

Data collection tools

The focus group is audio-recorded with two recorders and auto-transcribed through transcription software (WhisperAI). During the session, an animation video is used as a prompt and served as a conversation starter. Additional photos were taken to support the data.

Data analysis process

The data is analyzed using inductive thematic analysis. According to Braun and Clarke (2013), an inductive thematic analysis aims to generate an analysis from the bottom up. The analysis is not shaped by existing theory but is often used to understand participants' perceptions and beliefs. Since this method supports an iterative process, which could identify contextual implications to make the concept more tailored to the context of Schiphol Airport, an inductive thematic analysis is chosen. Data analysis will be conducted by the main researcher. The data will be analyzed according to the following workflow based on the work of Braun and Clarke (2013):

- Eliminate errors in the auto-transcription
- Read the full transcription (familiarisation)
- Start coding across entire dataset by grouping quotes in codes and code groups
- Search for themes and sub-themes
- Review themes and sub-themes
- Define and name themes
- Write and finalise analysis

Credibility strategies

- Participants from different departments (e.g., Human Resources, Bus director, Innovation Manager, Bus Service Owner, Service oriented role).
- The use of a moderator assistant, to reduce the main researcher's bias.
- External Confirmability audit, who provides critical feedback on the process, the data, and the intermediate results (Bryman and Bell, 2007).

E. Approved project brief

TU Delft

DESIGN FOR our future

IDE Master Graduation Project

Project team, procedural checks and Personal Project Brief

In this document the agreements made between student and supervisory team about the student's IDE Master Graduation Project are set out. This document may also include involvement of an external client, however does not cover any legal matters student and client (might) agree upon. Next to that, this document facilitates the required procedural checks:

- Student defines the team, what the student is going to do/deliver and how that will come about
- Chair of the supervisory team signs, to formally approve the project's setup / Project brief
- SSC E&SA (Shared Service Centre, Education & Student Affairs) report on the student's registration and study progress
- IDE's Board of Examiners confirms the proposed supervisory team on their eligibility, and whether the student is allowed to start the Graduation Project

STUDENT DATA & MASTER PROGRAMME

Complete all fields and indicate which master(s) you are in

Family name	van Dam
Initials	F L
Given name	Femke
Student number	4652150

IDE master(s): IPD ☐ Dfl ☐ SPD ✓

2nd non-IDE master:

Individual programme *(date of approval)*:

Medisign ☐

HPM ☐

SUPERVISORY TEAM

Fill in he required information of supervisory team members. If applicable, company mentor is added as 2nd mentor

Chair	Alessandro Bozzon	dept./section	SDE
mentor	Garoa Gomez Beldarrain	dept./section	DOS
2nd mentor			
client:	Royal Schiphol Group		
city:	Amsterdam	country:	The Netherlands
optional comments			

! Ensure a heterogeneous team. In case you wish to include team members from the same section, explain why.

! Chair should request the IDE Board of Examiners for approval when a non-IDE mentor is proposed. Include CV and motivation letter.

! 2nd mentor only applies when a client is involved.

APPROVAL OF CHAIR on PROJECT PROPOSAL / PROJECT BRIEF -> to be filled in by the Chair of the supervisory team

Sign for approval (Chair)

Name: Alessandro Bozzon Date: 30 Jan 2024 Signature: Alessandro Bozzon (Digitally signed by Alessandro Bozzon Date: 2024.01.30 11:43:19 +01'00')

CHECK ON STUDY PROGRESS

To be filled in by SSC E&SA (Shared Service Centre, Education & Student Affairs), after approval of the project brief by the chair.
The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total: ____ EC

Of which, taking conditional requirements into account, can be part of the exam programme: ____ EC

☐	YES	all 1st year master courses passed
☐	NO	missing 1st year courses

Comments:

Sign for approval (SSC E&SA)

Name: Date: Signature:

APPROVAL OF BOARD OF EXAMINERS IDE on SUPERVISORY TEAM -> to be checked and filled in by IDE's Board of Examiners

Does the composition of the Supervisory Team comply with regulations?

YES	☐	Supervisory Team approved
NO	☐	Supervisory Team not approved

Comments:

Based on study progress, students is ...

☐	ALLOWED to start the graduation project
☐	NOT allowed to start the graduation project

Comments:

Sign for approval (BoEx)

Name: Date: Signature:

DESIGN FOR our future | TU Delft

Personal Project Brief – IDE Master Graduation Project

Name student	Femke van Dam	**Student number**	4,652,150

PROJECT TITLE, INTRODUCTION, PROBLEM DEFINITION and ASSIGNMENT
Complete all fields, keep information clear, specific and concise

Project title Designing the future role of human operators in autonomous buses: a case study on Autonomous Airside Operations in Schiphol Airport

Please state the title of your graduation project (above). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

Introduction

Describe the context of your project here; What is the domain in which your project takes place? Who are the main stakeholders and what interests are at stake? Describe the opportunities (and limitations) in this domain to better serve the stakeholder interests. (max 250 words)

Royal Schiphol Group created a vision for 2050 to create the world's most sustainable and high-quality airport. Therefore, Schiphol has initiated the Autonomous Airside Operations team, which aims to make all vehicles and processes on the airside sustainable and autonomous. Automated vehicles at airside can enhance the efficiency and safety at the airport. Schiphol is currently testing its first autonomous bus on a fixed route on airside, where the cleaning personnel operates as the passengers, and a safety driver is present for manual takeover. After finishing the testing phase in May 2024, the bus system will be used for the transportation of the flight crew towards passenger flights and there might be a possibility that the buses will be used for passengers in the future (figure 1). Eventhough Schiphol cites that in time, it will be technically possible to fully automate nearly all airport processes, the human touch will remain an essential part of their good service proposition: Schiphol aims for a highly personalized and memorable experience. "In a world where the necessity of human interaction has almost completely disappeared and touchless technology is the standard, we distinguish ourselves through our people, who 'go the extra mile' to make passengers feel welcome and valued." (Schiphol, 2020). Therefore, the challenge for Schiphol is to determine a future human role within the context of an autonomous airside. Initiatives have already focused on new roles within autonomous buses: this year, the world's first autonomous bus service was launched, with a safety driver for manual takeovers and a 'bus captain' dedicated to facilitating a smoother bus journey for passengers (CAVForth, 2023). This new role could be an opportunity for Schiphol to enhance their service proposition.

➔ *space available for images / figures on next page*

introduction (continued): space for images

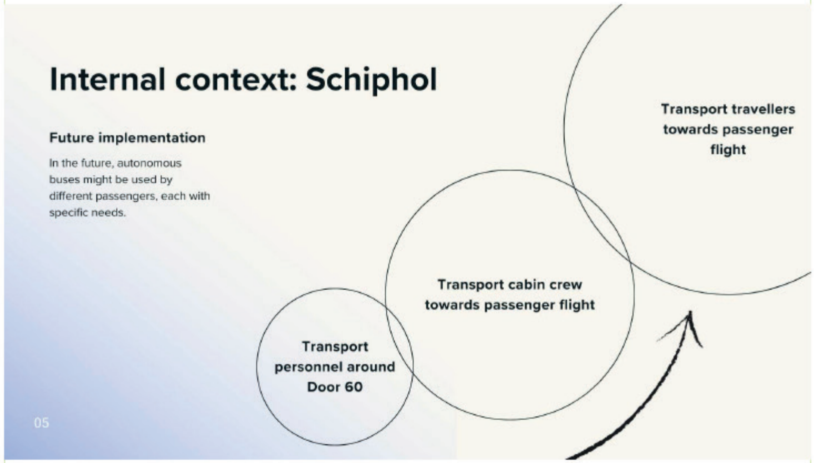


image / figure 1 Future implementation of autonomous buses in Airside Operations

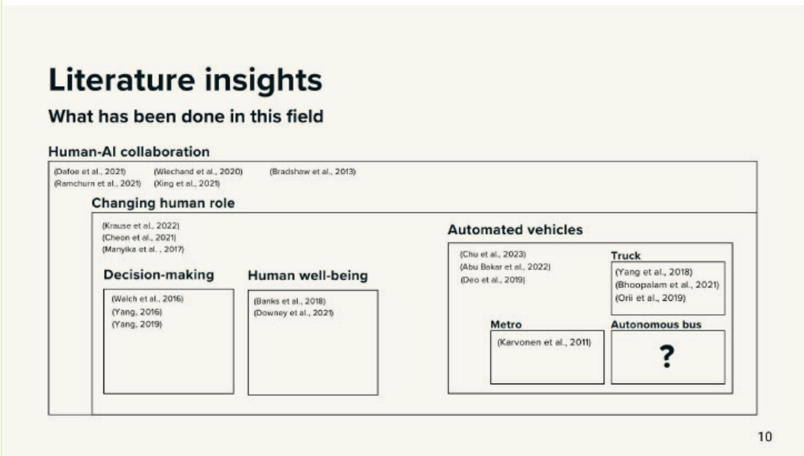


image / figure 2 Gap in the (initial) literature

DESIGN FOR our future

TU Delft

Personal Project Brief – IDE Master Graduation Project

Problem Definition

What problem do you want to solve in the context described in the introduction, and within the available time frame of 100 working days? (= Master Graduation Project of 30 EC). What opportunities do you see to create added value for the described stakeholders? Substantiate your choice.
(max 200 words)

Literature shows that human supervision is still essential and the human-AI relationship needs to be more cooperative (Chu et al., 2023). Therefore, the human role will change in the future (Bradshaw, 2013) and this role needs to be further clarified (Xing et al., 2021). Extensive literature research is done about the role of the safety driver in autonomous vehicles, mainly from a passenger experience lens, but no research is done about the human operator perspective in the context of an autonomous bus system (figure 2).

Schiphol is assuming that the human touch is necessary to remain a good service proposition in an autonomous airside. However, the interpretation or 'job description' of these human roles has not been determined. Therefore, this shift on how the role of human operators transform over time and how this would look like in the context of Airport Operations must be examined.

The goal of this research is to design the future human operator role by understanding how the role of human operators change over time in the context of autonomous buses in Airport operations.

Assignment

This is the most important part of the project brief because it will give a clear direction of what you are heading for. Formulate an assignment to yourself regarding what you expect to deliver as result at the end of your project. (1 sentence)
As you graduate as an industrial design engineer, your assignment will start with a verb (Design/Investigate/Validate/Create), and you may use the green text format:

Design the human operator role in the context of autonomous buses in Autonomous Airport Operations by (1) understanding how the operator role changes over time and by (2) assessing a future human operator concept in an autonomous bus.

Then explain your project approach to carrying out your graduation project and what research and design methods you plan to use to generate your design solution (max 150 words)

First, stakeholders (e.g., safety drivers, bus drivers, management-level employees, etc.) will be decided and mapped out. Based on in-depth interviews, their perceptions, expectations, and needs towards the future role of human operators are determined. After that, values for the role are distilled. Next, an intervention in the context of the autonomous bus is designed based on the values. The intervention will be tested and the perceived experience among passengers will be evaluated. I will end the project by examining thow the role of human operators could be integrated in a transition towards an Autonomous Airside.

Project planning and key moments

To make visible how you plan to spend your time, you must make a planning for the full project. You are advised to use a Gantt chart format to show the different phases of your project, deliverables you have in mind, meetings and in-between deadlines. Keep in mind that all activities should fit within the given run time of 100 working days. Your planning should include a ***kick-off meeting, mid-term evaluation meeting, green light meeting and graduation ceremony.*** *Please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any (for instance because of holidays or parallel course activities).*

Make sure to attach the full plan to this project brief.
The four key moment dates must be filled in below

Kick off meeting	17 jan 2024
Mid-term evaluation	5 apr 2024
Green light meeting	7 juni 2024
Graduation ceremony	5 juli 2024

In exceptional cases (part of) the Graduation Project may need to be scheduled part-time. Indicate here if such applies to your project

Part of project scheduled part-time	
For how many project weeks	
Number of project days per week	

Comments:

Motivation and personal ambitions

Explain why you wish to start this project, what competencies you want to prove or develop (e.g. competencies acquired in your MSc programme, electives, extra-curricular activities or other).

Optionally, describe whether you have some personal learning ambitions which you explicitly want to address in this project, on top of the learning objectives of the Graduation Project itself. You might think of e.g. acquiring in depth knowledge on a specific subject, broadening your competencies or experimenting with a specific tool or methodology. Personal learning ambitions are limited to a maximum number of five.
(200 words max)

I am looking forward to start this project because my passion lies within the field of mobility: previously, I was part of the TU Eco-Runner Dreamteam where we successfully designed and built the world's most efficient hydrogen-powered city car. And during the SPD Research course, I worked on a research project focused on the acceptance of E-ID in Seamless Commercial Flight Travel. I hope to further develop expertise in mobility during my graduation project. I would like to prove my competencies in conducting in-depth interviews and visualizing concepts. I would like to further develop my academic writing, my collaboration with various stakeholders and I hope to gain knowledge about human-centered principles in travel. Also, I would like to experience how it is to work as a researcher in a new work environment at Schiphol. My personal learning ambition is to use co-creation in designing the intervention during the project with not only management-level stakeholders but also operator-level employees.