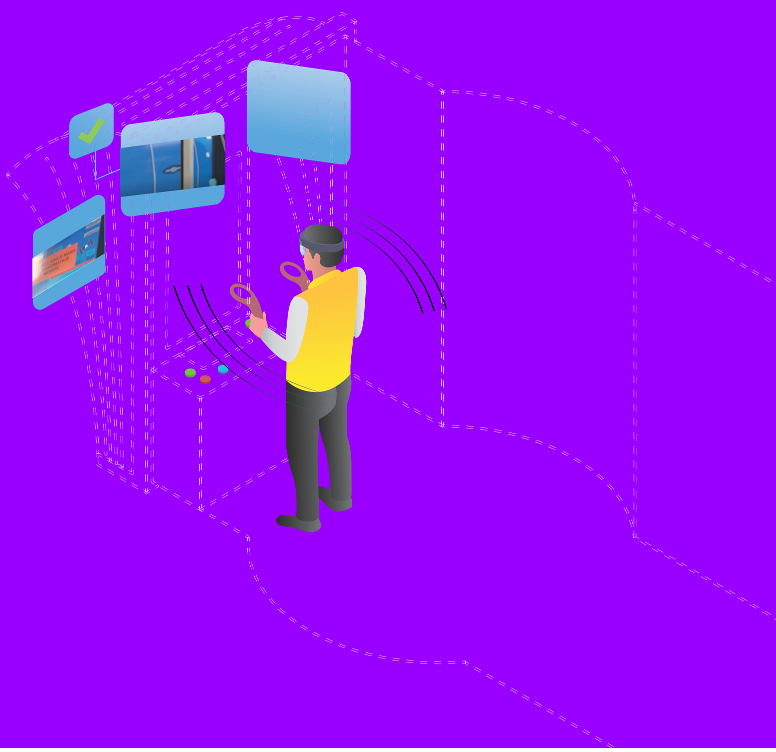
Master Thesis

Framing a Guideline for Balancing Task Delegation of Human-Robot Collaboration in Automation Processes

A Case Study of an Automatic Passenger Boarding Bridge in Amsterdam-Based Airport Autonomous Airside Operation



Jeongha Joo

MSc Design for Interaction

August. 22nd 2023

The Royal Schiphol Group (RSG) and Delft University of Technology (TU Delft) have a joint collaboration to focus on the airport process and passenger experience. Together, they aim to take a creative and accelerated approach to develop new innovative projects by examining which processes, technologies, applications, and travel modalities contribute to seamless travel experiences in a sustainable, flexible, and multimodal transport hub in the aviation industry (Accelerating Innovation, n.d.). TU Delft's Faculty of Industrial Design Engineering will contribute with expertise in design, and Schiphol will serve as an experimental site at the airports.

RSG has set an ambitious goal of operating sustainable airports worldwide by 2050 (Schiphol | Een Autonome Luchthaven in 2050, 2020). In pursuit of this objective, RSG is not only committed to reducing CO2 emissions, but also improving the working environment in and around the airport while ensuring safety and making the most efficient use of its capacity. To this end, RSG has launched a project, Autonomous Airside Operations (AAO), which aims to make all vehicles and associated processes on the airside sustainable and autonomous. The project belongs to the AAO team, which is part of the Strategy and Airport Planning department (SA&P) of the Innovation Hub within RSG, working on the future of RSG.

This master thesis is a part of the Ph.D. research of Garoa Gomez-Beldarrain, which explores the adaptation of automation in organizations, with a particular focus on the AAO, at the faculty of Industrial Design Engineering at Delft University of Technology.

Master Thesis

August 22nd, 2023
Delft, Netherlands

Author

Jeongha Joo

Education

MSc. Design for Interaction
Faculty of Industrial Design Engineering
Delft University of Technology

Supervisory team

Dr. Himanshu Verma
Assistant Professor
The Knowledge and Intelligence Design (KInD)
Department of Sustainable Design Engineering
Delft University of Technology

Dr. Eui Young Kim
Design, Organization, and Strategy (DOS) department
Co-director of the Automated Mobility Lab
Delft University of Technology

MSc. Garoa Gomez-Beldarrain
Ph.D Candidate
The Knowledge and Intelligence Design (KInD)
Design, Organization, and Strategy (DOS) departmen
Delft University of Technology

Collaboration

Rosina Kotey
Innovation Lead
Innovation Hub in Royal Schiphol Group

Acknowledgements

With a passion for exploring innovation of mobility with cutting-edge technology, I eagerly took an innovative project in the aviation industry for my graduation. In addition to exploring AI, digital transformation, and multiverse from the master's program of Design for Interaction, working as a graduate intern at RSG allowed me to synthesize knowledge from research and practical insights. Now, as I reach the end of my two-year master's journey, I can't contain my excitement and joy. It's an incredible feeling to see this journey come to a successful close.

First and foremost, I would like to express my sincere gratitude to my esteemed supervisor team, Himanshu Verma, Eui Young Kim, and Garoa Gomez-Beldarrain, for their invaluable guidance, expertise, and continuous support throughout this research project. Their insights, constructive feedback, and encouragement have played a pivotal role in shaping the direction and quality of this study. I am deeply grateful for the opportunity to work under their supervision and their commitment to my academic growth.

I would also like to extend my appreciation to the Innovation Hub team from the Royal Schiphol Group, especially my company mentor, Rosina Kotey, for providing the necessary resources and support that enabled me to conduct this study. Their support has been crucial in the successful completion of this research.

I am sincerely grateful to my family in Korea for their unwavering encouragement from a long distance. Their love, support, and belief in me have been a constant source of motivation.

Lastly, I would like to express my heartfelt appreciation to my lifelong partner, Beomjin, for his support and understanding. His presence and encouragement in this foreign country have been invaluable in keeping me focused and motivated during challenging times. In particular, I am truly grateful for his valuable contributions, including his assistance in brainstorming for the project outputs, which played a significant role in keeping the momentum and progress of my work.

Without the support and contributions of these individuals, this research would not have been possible. I am sincerely grateful for their involvement and would like to acknowledge their significant role in completing this study.

Abbreviation

AAS = Amsterdam Airport Schiphol

RSG = Royal Schiphol Group

AAO = Autonomous Airside Operations

HRC = Human-Robot Collaboration

HRI = Human-Robot Interaction

HAC = Human-Automatioin Collaboration

LOA = Levels of Autonomy

AS = Automated System

PBB = Passenger Boarding Bridge

APBB = Automatic Passenger Boarding Bridge

MPBB = Manual Passenger Boarding Bridge

Executive Summary

As automation technology continues to transform various industries, achieving both high operational reliability and high efficiency emerges as a critical challenge in task delegation between humans and Automated Systems (ASs). This project, conducted in collaboration with the Royal Schiphol Group (RSG), investigates the intricate dynamics of Human-Automation Collaboration (HAC) in the context of Passenger Boarding Bridge (PBB) operations at the Amsterdam Airport Schiphol. The design goal is for organizations to strike a balance between the decision-making authority retained by humans, and that can be transferred to ASs. Through a combination of literature study, context research, in-depth interviews, and surveys, this study synthesizes insights to understand the changing nature of tasks between humans and ASs, identify influential factors, and determine the appropriate level of human involvement in task delegations.

In the preliminary research phase, two main activities were conducted: a literature study and context research. The literature study clarified the academic terminologies used in this research and identified seven key considerations in Human-Robot Collaboration (HRC) and task delegation as fundamentals for the primary research planning: time and space, Levels of Autonomy (LoA), task specification, team composition, capabilities, human preferences, and costs.

Simultaneously, in context research, from understanding the Turn Around journey on the airside, which encompasses the activities between the arrival of an aircraft and its departure, a specific scope was reframed: Passenger Boarding Bridge (PBB) at AAS. Moreover, three expert interviews and one shadowing were conducted to understand how operators work with Automatic Passenger Boarding Bridge (APBB). With the findings that PBB may come in different types, such as a semi-automatic bridge controlled inside and outside the PBB, the main research question was reframed for the primary research as below:

> *RQ: In the different PBB operation types (e.g., semi-auto controlled in a PBB, semi-auto controlled outside PBB), how can we better understand which tasks can be delegated to ASs, and which tasks humans should perform?*

The findings from the primary research (i.e., in-depth interviews and survey) highlight the concrete implications regarding task delegation revealed 12 themes with four dimensions, identifying the nuanced strengths and weaknesses of both humans and ASs in PBB operations. High-precision tasks are identified as potential candidates for AS delegation, while tasks requiring clear communication and meticulous inspection align better with human management. The study underscores the significance of effective information exchange, emphasizing the multifaceted roles of humans beyond mere data exchange.

The research outcomes highlight two controversial values relevant to task delegation: 1) the significance of reliability in ensuring a comprehensive perspective and 2) efficiency through accuracy, with distinct viewpoints between decision-makers and operators.

To effectively discuss these controversial values and perspectives, the design direction entails simulating possible scenarios in the transition of different types of PBB control to allow organizations to confront 1) different perspectives of the decision-making process in task delegation, 2) two different values (i.e., the importance of reliability assuring a holistic situation and of efficiency by accuracy), and 3) diverse scenarios caused by decision-making and different variables.

A speculative board game was developed as a probing tool based on 12 themes and four themes from the primary research and evaluated to achieve the design direction. Through the evaluation, the game exhibits the potential to encourage stakeholders to confront diverse perspectives on task delegation and facilitate an empathetic understanding each other, stimulating discussions about the balance between reliability and efficiency and fostering strategic considerations related to automation.

As a synthesized output of this study, a comprehensive roadmap to envision a future vision for RSG by the year 2050 is formulated, aligning with the goal to operate sustainable airports. The envisioned future involves a hybrid HAC approach, where humans oversee operations remotely, potentially with virtual or augmented reality, and ASs specialize in high-precision tasks. The roadmap encompasses three horizons with the categories of team composition, task specification, challenges of task delegation, interaction platforms, and technology considerations.

In conclusion, this research contributes valuable insights into the dynamic field of HAC by offering a comprehensive understanding on the intricate interplay between humans and automation. The findings are expected to provide a guideline for organizations seeking to optimize PBB operations, and the developed probing tool and roadmap are expected to serve as practical tools for strategic decision-making in task delegation between humans and ASs toward enhancing both reliability and efficiency in airside operations.

Table of Contents

1. Introduction

This introductory section provides an overview of the research objectives, challenges, the significance of exploring the context of Autonomous Airside Operations (AAO), and research questions regarding the challenges and objectives.

1.1. Background

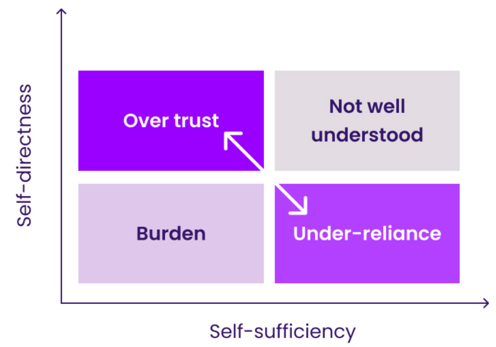
1.1.1. Task Delegation in HRC

The advance of automation technology (e.g., artificial intelligence and sensor technologies) has made it increasingly possible to benefit our lives (Hopko et al., 2022; Janssen et al., 2019). Automated Systems (ASs) have benefits in that robots can manipulate heavy payloads, perform repetitious tasks, or work in unsafe environments in place of humans (Hopko et al., 2022). If we can increasingly delegate our tasks to ASs, we may no longer need to be 'in the loop' (that is, as part of the process or at least in control of it).

However, automation cannot fully function independently without humans (Bradshaw et al., 2013). If we misuse automation technologies, there is a risk of handing over crucial tasks and decisions to autonomous systems that should still be partially under human supervision and control (Floridi et al., 2018), leading to challenges (Figure 1.1). If people working with ASs do not fully comprehend their capabilities (Bradshaw et al., 2013), it may cause “over-trust” or “under-reliance.” “Over-trust” in ASs can lead to “complacency,” where operators may become less vigilant in monitoring automation (by no longer being ‘on the loop’ either) and fail to identify and redress errors or anomalies (‘post loop’) (Bradshaw et al., 2013; Floridi et al., 2018). This is particularly problematic when the system is highly reliable but not completely error-free (Parasuraman et al., 1993). Operators may become overly reliant on the ASs' performance, potentially overlooking critical issues or being caught off guard by unexpected failures, such as pilots being forced to take manual control during a flight (Carr, 2015). On the other hand, "under-reliance" may occur, which refers to a situation where a human operator or policy prohibits a system from performing a set of actions despite the machine's sufficient competence to do so (Bradshaw et al., 2013) due to a lack of trust in the system.

Therefore, it is critical to strike a balance between the decision-making authority retained by humans and that can be transferred to ASs (Cila, 2022; Floridi et al., 2018). To achieve this, a thorough understanding of the capabilities of both humans and ASs is essential, investigating considerations of task delegation. During the initial phase of collaboration, recognizing the strengths and limitations of each party becomes crucial for effective task delegation (Cila, 2022; Dearden et al., 2000).

In this regard, this research aims to frame a conceptual guideline by which organizations can envision a future vision that delegates tasks between humans and automation and keep humans in the loop, yielding a well-rounded understanding of task delegation. In decision-making, Identifying which tasks can be allocated to robots and which should be continuously performed by humans can aid in recognizing situations where the transfer of control is necessary and effectively employs human judgment for critical decision-making tasks (Russell et al., 2015). Ultimately, this research aims for organizations to optimize task allocation effectively while preserving the essential role of human input.



[Figure 1.1 Challenges of autonomous machine capabilities (Bradshaw et al., 2013, p.3)]

1.1.2. Case study of Autonomous Airside Operations (AAO) in the Amsterdam Airport Schiphol (AAS)

With the purpose discussed, the research was conducted in the context of Schiphol AAO team (Figure 2.1). The case study provides concrete implications regarding task delegations, as understanding the user needs and the specific use context is crucial to identify these tasks (Cila, 2022).

The significance of exploring AAO

Airports are complex environments that combine features of both cities and factories (Csiszár, 2014). On the one hand, they resemble cities in their diversity, complexity, and unpredictability. On the other hand, they also resemble factories using automation and control systems in a hierarchical setting. By utilizing automation technology, airports can be an ideal test base for studying implemented AS as a semi-controllable environment.

Airports can be divided into two main sections: the landside and the airside. The landside is the area of the airport terminal building where passengers arrive and depart, while the airside is the area dedicated to aircraft operations, including loading, unloading, takeoffs, and landings. As the research was initiated by the AAO team at the Innovation Hub, the research foucsed on the airside context.

The airside, where various vehicles, aircraft, and workers collaborate in preparing an aircraft for departure in the Turnaround procedure, is a dynamic environment. This procedure requires the clear collaboration of multiple stakeholders, including ground-handling companies, airlines, and different airport departments, to ensure safe operation and on-time performance. However, the airside poses challenges due to its high-risk and hazardous nature, with workers exposed to demanding workload and unexpected incidents that can impact their well-being. The transition of autonomous Turn around procedures expects to help reduce human exposure to these risks by delegating risky tasks to automated systems and improving operational efficiency, such as controlling all the Turn around procedures remotely while systems work automatically in the field.

While automation technologies for airport operations (e.g., smart sensors) are relatively feasible, human factors involved in task delegation remain under development (F. Liu & Zuo, 2011). Due to the hard-working conditions, the airports have been facing a labor shortage as one of the challenges. Additionally, concerns regarding job displacement by ASs have been raised. Therefore, it is important to consider the experiences of airside workers collaborating with ASs (Saadati et al., 2022)

Given these considerations, the airside can provide an ideal research environment for implementing ASs in real-world scenarios involving human factors. Delegating risky tasks to ASs can benefit workers' work environments and improve work efficiency (Bouzekri et al., 2019). Therefore, there is a research opportunity to understand how task delegation between Humans and ASs could be achieved on the airside.

1.1.3. Challenges

How might we design an explicit task delegation guideline to maintain an appropriate level of human involvement while benefiting the work environment and the efficiency of operations when collaborating with ASs in airfield operations?

Task delegation in HRC presents several challenges that need to be addressed.

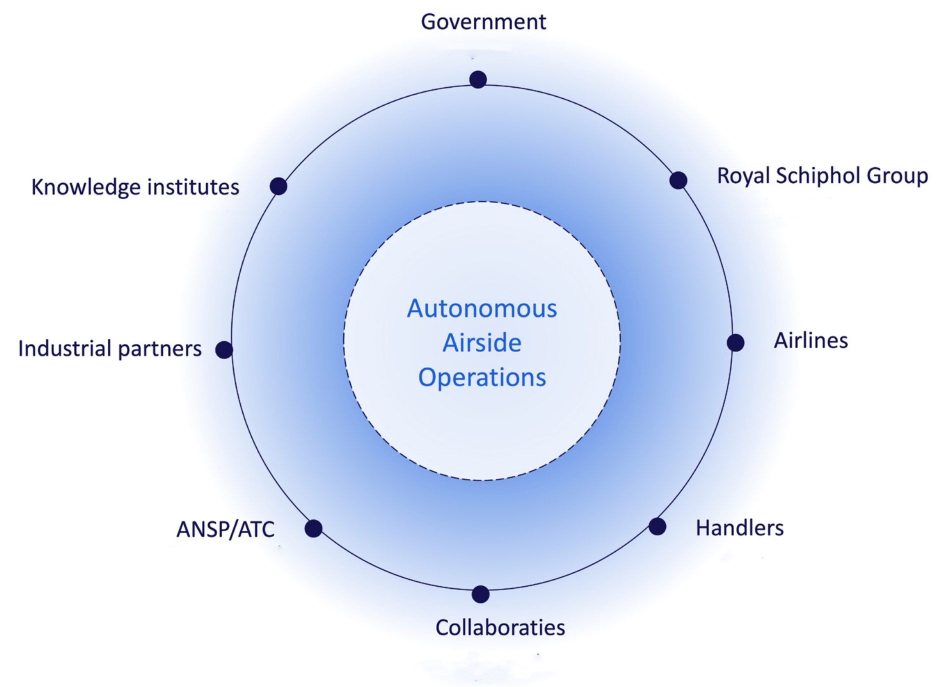
- Striking a balance between the decision-making authority retained by humans and that can be transferred to ASs
- Understanding the changing nature of tasks for humans and ASs
- Identifying the influential factors that impact the delegation process in HRC
- Finding the appropriate level of human involvement in HRC

Research Questions

RQ1. What influential factors can be considered in task delegation between humans and ASs for efficient airside operations?

RQ2. How can organizations better understand what tasks can be delegated to the AS, and which should humans perform?

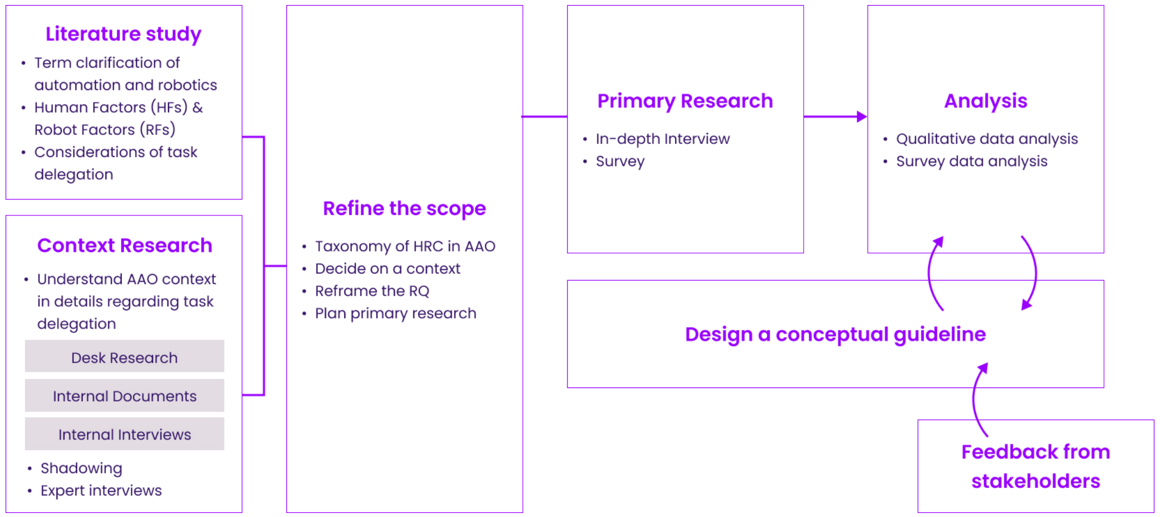
By answering these questions, the study aims to provide a vision for managing the dynamic nature of airport operations, benefiting passengers, airlines, and other stakeholders. Through a specific case study, this research expects to provide a conceptual guideline for designing task delegation in HRC, investigating human factors.



[Figure 2.1: Stakedholders in AAO team (Kotey, R., internal meeting, February 14, 2023)]

1.2. Project Approach

Figure 1.2 illustrates the overall project approach. The research started with a literature study (Chapter 2) and context research (Chapter 3) simultaneously. The Literature study enabled to clarify academic terminologies that this research used. It also guided the narrowing of the focus among many steps in the Turn Around journey on the airside, which stemmed from the context research. Synthesizing implications from both pieces of research led to reframing the scope and deciding on the Passenger Boarding Bridge (PBB) as a domain. Moreover, the primary research (i.e., in-depth Interviews, shadowing, survey) was conducted while outlining a conceptual guideline as a main output. Lastly, evaluation sessions of the design with stakeholders led to meaningful feedback with some implications for future research.



[Figure 1.3: Project overview]

2. Literature study

The following literature study has two primary objectives. The first aim is to clarify the terminology regarding automation, robot, and task delegation, as different stakeholders have diverse perspectives and understandings of these terms. This clarification is crucial in ensuring precise and consistent communication in the study.

Secondly, the study seeks to enhance understanding of the challenges of task delegation in HRC. Examining the characteristics of HRC and task delegation facilitates the identification of key factors in task delegation, leading to further research direction. The insights gained from this literature study will contribute to a foundation for guiding further research and analysis conducted in this study, fostering advancements in the effective implementation of task delegation in HRC.

2.1. Automation and Robots

Why

At the start of the project, there was a lack of clarity and consistency in the communication regarding the definitions of terminologies related to automation and robots. Different stakeholders, designers, and researchers often used these terms interchangeably, leading to confusion. Some individuals interpreted mechanical systems and equipment as components of robots, whereas others considered them machines manually controlled by humans without any automation or robotics involved.

What

The term automation derives from the Greek word automatos, meaning to behave autonomously, voluntarily, or spontaneously (Nof, 2009). It has evolved with relateerms such as mechanization, cybernetics, artificial intelligence, and robotics. Therefore, automation or robotics involves autonomous capability in the system with the independence of human control.

2.1.1. Automation

Automation, involving self-acting and self-moving, is the capability of the system self-making decisions and carrying out actions without human intervention (Nof, 2009). Beer (2014) defines autonomy as the extent to which a system can sense, plan, and act within its environment with the goal of achieving a task-specific objective without external control. It can respond to external stimuli and follow a predetermined set of instructions or programs with its power source to function. According to the Britannica encyclopedia, automation is “the application of machines to tasks once performed by human beings or, increasingly, to tasks that would otherwise be impossible. Although the term mechanization is often used to refer to the simple replacement of human labor by machines, automation generally implies the integration of machines into a self-governing system (Groover, 2023).”

2.1.2. Robot and robotics

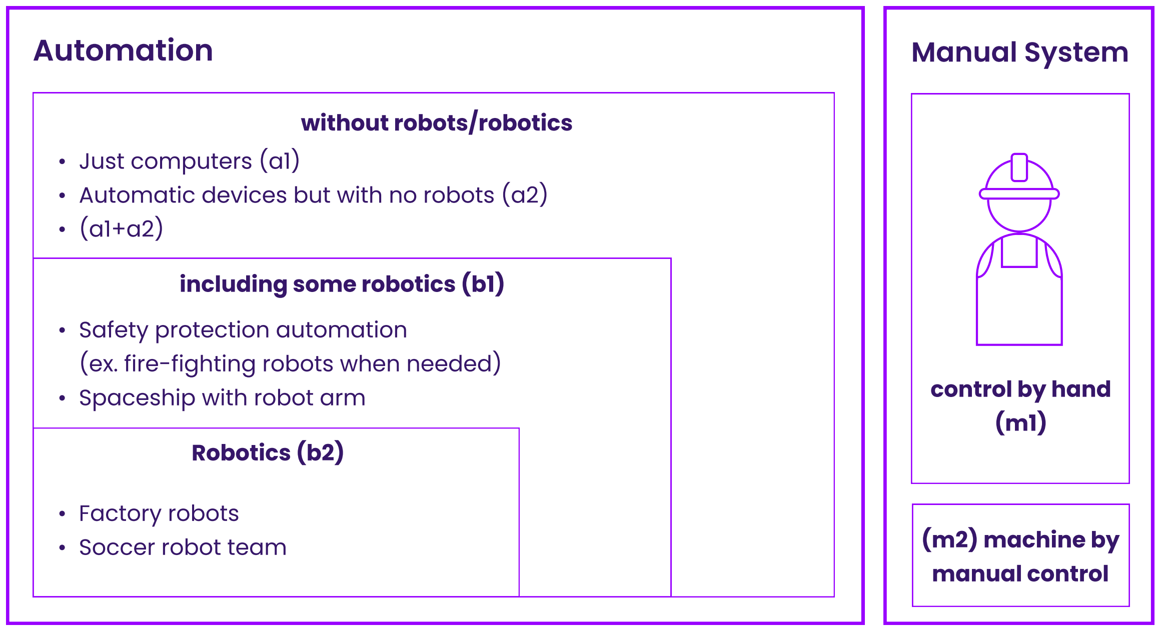
A robot is “a programmed actuated mechanism with a degree of autonomy to perform locomotion, manipulation, or positioning under control system” (ISO 8373:2021(En), Robotics — Vocabulary, n.d.). It can have different structures of robots such as manipulators, mobile platform, and wearable robots. It can replace human effort as an automatically operated machine (Moravec, 2022). Unlike an automation, a robot is usually designed to perform flexible, variable movements and activities for specific operation domains such as surgery, service, welding, and toy (Nof, 2009). Moreover, robotics is “the science and technology of designing, building, and applying robots, computer-controlled mechanical devices, such as automated tools and machines” (Nof, 2009).

2.1.3. The relation between robotics and automation

Automation encompasses various domains beyond robotics, such as infrastructure, non-robot devices, machines, installations, and systems (Nof, 2009). As seen in Figure 2.1, automation includes applications (a1) with just computers, (a2) with various automation platforms and applications, but without robots; (b1) automation including some robotics; (b2) automation with robotics. While robotics focuses on physical platforms for motion and mobility, automation beyond robotics involves software for decision-making, planning, optimization, collaboration, and other managerial aspects of the automation process (Nof, 2009). Defining the distinct scope within automation will be the basis for understanding the extent to which automation has been implemented in the case of airports.

2.1.4. Takeaways

- Automation spans various domains beyond robotics, encompassing infrastructure, non-robotic devices, machines, installations, and systems (Nof, 2009). To ensure clarity in this study, the term "Automated Systems (ASs)" will be predominantly used to encompass different types of automation beyond robots.
- Autonomy, defined by Beer (2014) as a system's ability to Sense, Plan, and Act within its environment to achieve a specific task without external control, will be used to frame the primary research.
- Defining the distinct scope within automation (m1,m2,a1,a2,b1,b2) will be the basis for a context study (Chapter 3) to understand the level of automation implemented in airports and its various facets.



[Figure 2.1: The relation between robotics and automation modified from (Nof, 2009)]

2.2. Features of HRC in Operations

Why

Studying the features of collaboration between humans and robots during operations provides key considerations when delegating tasks to either humans or robots. This research aids in improving our comprehension of human-robot teamwork dynamics.

What

The literature study revealed multiple features to consider in HRC, which are important to have holistic views of these features. One commensurable factor is not enough to describe the depth of collaboration (Aaltonen et al., 2018a). In this part, four factors will be described as shown in Figure 2.2 : 1) Time and Space (i.e., when and where the HRC occurs), 2) Level of Autonomy (i.e., how ASs collaborate with humans), 3) Robot task specification (i.e., which tasks ASs can perform), 4) Team composition (i.e., how ASs and human can be composed as team members).

How

The investigation involved three main papers (Aaltonen et al., 2018a; Kopp et al., 2021; Onnasch & Roesler, 2021) that focused on HRC. hese papers extensively reviewed prior research in the field, presenting a comprehensive synthesis of related concepts and characteristics. Aaltonen et al. (2018) proposed collaboration levels based on the analysis of seven previous studies. Onnash & Roesler (2021) proposed a framework for analyzing HRI, considering elements such as the human, robot, interaction, and context, drawing on 13 taxonomy examples. The research by Kopp et al.(2021) contributed to the understanding of various interaction types and their specific features between humans and robots. The collective findings of these reviews offer an integrated overview of the characteristics of Human-Robot Interaction (HRI) or Human-Robot Collaboration (HRC).

Factors	Description	Reference
Time and Space	Proximity in temporal and physical aspects; cell, coexistence, synchronization, cooperation, collaboration	Aaltonen et al., 2018a; Kopp et al., 2021; Onnasch & Roesler, 2021; Wilhelm et al., 2016
	the nature of the environment	Beer et al., 2014; Desai et al., 2009;
Levels of Autonomy	Sense, Plan, and Act	Beer et al., 2014; Kaber & Endsley, 2004; Parasuraman et al., 2000; Parasuraman, 2010; Pacaux, 2011
Robot task specification	8 tasks: 1) Information exchange, 2) precision, 3) physical load reduction, 4) transport, 5) manipulation, 6) cognitive stimulation, 7) emotional stimulation, and 8) physical stimulation	Onnasch & Roesler, 2021
Team composition	1) having an equal number of humans and robots (Nh=Nr) 2) having more humans than robots (Nh>Nr) 3) having more robots than humans (Nh<Nr)	Onnasch & Roesler, 2021

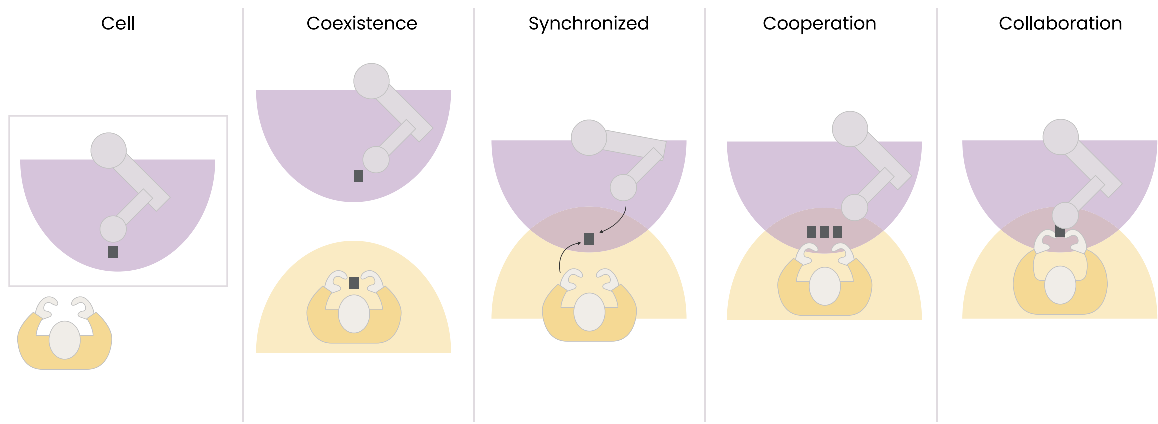
[Figure 2.2 Overview of four elements in HRC

2.2.1. Time and Space

Proximity in temporal and physical aspects is critical in HRC. Onnash & Roesler (2021) indicated the temporal (i.e., synchronous and asynchronous) and physical contact (e.g., following, touching, passing) as one of HRC characteristics. Due to safety issues, to prevent incidental contact between humans and robots, the robots have performed separate tasks in a completely separate time and space from humans. This is achieved by placing the robots within safeguards that are restricted to human access (referred to as "cell" (Aaltonen et al., 2018a; Kopp et al., 2021; Wilhelm et al., 2016)) or by implementing a security mechanism that causes the robot to stop moving as soon as it detects human contact in the work environment (referred to as "coexistence") (Aaltonen et al., 2018a; Kopp et al., 2021). Moreover, humans and robots can share the same working area in cooperative circumstances; however, working on the same task sequentially (the so-called "synchroized" (Wilhelm et al., 2016) or timely separated with different tasks (so-called "cooperation" (Aaltonen et al., 2018a; Kopp et al., 2021)). In other words, they join the working environment one after the other, such that a person and a robot are not simultaneously present in the same working space. The overview of different HRC types can be seen in Figure 2.3.

However, in contrast to "cell," "coexistence," and "cooperation," the concept of collaboration in HRC refers to the simultaneous work of humans and robots on the same task (Kopp et al., 2021), within the same working environment (ISO definition 8373:2021) and executing a collaborative work activity (Aaltonen et al., 2018b). Therefore, whereas traditional industrial robots require to be physically separated from humans for safety reasons, HRC allows for a broader range of temporal overlaps and physical contact possibilities.

Moreover, the nature of the environment should be considered (Beer et al., 2014). The AS's capability to operate in a dynamic environment largely depends on environmental conditions that influence the robot's sensors' ability to comprehend the surroundings (Beer et al., 2014). However, not all environment characteristics can be predicted by the ASs, such as illumination, surface reflectivity, or glare through camera sensors. Therefore, the presence of a human supervisor may be required for complex activities (Desai et al., 2009).



[Figure 2.3 The different types of HRC (Wilhelm et al., 2016)]

2.2.2 Levels of Autonomy (LoA)

Levels of Autonomy (LOA) is one of the critical characteristics in designing HRC. Establishing achievable levels of autonomy in automated systems is closely related to different types of interaction with humans. Several research proposed autonomy levels, with similar categories in Table 2.1.

In the most recent research, Beer et al. (2014) stated that determining the robot's autonomy requires a clarification of how to measure the extent to which a robot can perform each task aspect, Sense, Plan, and Act primitive as seen in Figure 2.4. The basis of Sense, Plan, and Act could be allocated to either the human or the robot (or both). However, what is important is to note that autonomy is a continuum and understand that there are blurred borders between the proposed categories (Beer et al., 2014).

Reference	Step 1	Step 2	Step 3	Step 4
Parasuraman et al., 2000	Acquisition of multiple sources of information (sensory processing, preprocessing of data, and selective attention)	Manipulation of information in working memory and cognitive operations such as integration, diagnosis, and inference, occurring prior to the point of decision.	Decisions based on such cognitive processing	Entailment of an action consistent with the decision choice
Kaber & Endsley, 2004	Monitoring	Generating	Selecting	Implementing
Parasuraman, 2010	Information Acquisition	Information Analysis	Decision selection	Action implementation
Pacaux, 2011	info gathering	diagnosis	Decision-making	Action implementation
Beer et al.., 2014	Sense	Plan (Decision)		Act

[Table 2.1 Prior research on Levels of Automation (LoA)]

2.2.3 Robot task specification

The robot's function has strong impact on the interaction of human and robot. Depending on the tasks that the robot take, the interaction can be diverse. Onnasch & Roesler (2021) presented 8 specific tasks that robots can take: Information exchange, precision, physical load reduction, transport, manipulation, cognitive stimulation, emotional stimulation, and physical stimulation.

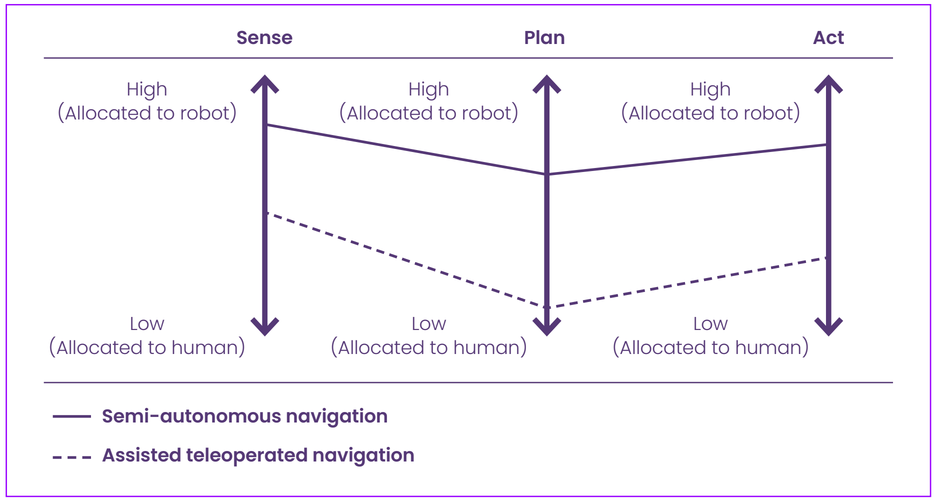
2.2.4 Team composition

Another factor that needs to be considered in HRC is team composition. The ratio of human workers to ASs can raise ethical concerns when implementing ASs and delegating tasks, as ASs have the potential to replace the need for multiple human workers in the field. There are three possible scenarios: having an equal number of humans and robots (Nh=Nr), having more humans than robots (Nh>Nr), and having more robots than humans (Nh<Nr) (Onnasch & Roesler, 2021). Therefore team composition could be a useful indicator for decision-makers to consider.

2.2.5. Takeaways

Multiple perspectives should be considered to ensure a holistic understanding of HRI or HRC. Therefore, this research will employ **four factors - time and space, levels of autonomy, robot task specification, and team composition** - as an approach

- As for time and space, HRC allows for a broader range of temporal overlaps and physical contact possibilities, alongside addressing the dynamic environment and the potential for technical errors.
- Levels of autonomy (LOA) are not fixed categories but represent a continuum, blurring the boundaries between proposed levels.
- Defining specific tasks suitable for automation will aid in understanding different tasks in AAO effectively.
- Team composition should be factored in when task delegation occurs, ensuring a balanced number of workers and ASs from an organizational perspective.



[Figure 2.4 Levels of autonomy across the robot primitives Sense, Plan , and Act (Beer et al., 2014, p. 85)]

2.3. Task Delegation

2.3.1. Definition of Task Delegation

It is crucial to define the concept of task delegation. The term delegation is often used synonymously with task allocation; however, there is a distinction according to the Oxford Dictionary and the literature. Delegation refers to "the process of giving somebody work or responsibilities that would usually be yours," while allocation pertains to "the act of giving something to somebody for a particular purpose." Compared to the meaning of allocation, delegation encompasses the aspect of responsibility (Landen, 2011). Therefore, delegation is a specific terminology to consider the responsibility of assigning tasks beyond allocating tasks.

In task delegation, the technology development highlights the significance of responsibility, having a question: **What task is the agent, which encompasses smart products, robots, and software agents, to perform? And how?** (Cila, 2022; Lubars & Tan, 2019) When individuals collaborate with ASs, they are willing to hand over some of their decision-making power to technology (Cila, 2022). Moreover, only they are responsible for determining how many levels of authority are delegated to ASs (Bradshaw et al., 2013). As ASs gain more autonomy and are viewed as teammates, allocating responsibility can be divided between the AS and the human (Beer et al., 2014).

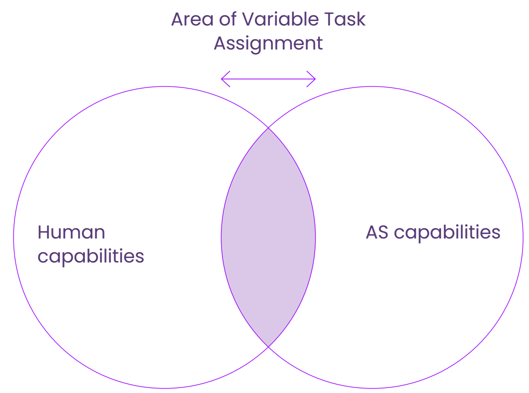
2.3.2. What tasks to delegate

In the context of HRC, the initial step in task delegation is crucial (Cila, 2022). Three key dimensions can guide this decision-making process in delegating tasks: 1) capability, 2) human preferences, and 3) cost, as supported by prior research (Bertrandias et al., 2021; Dearden et al., 2000; Gil et al., 2020; Hopko et al., 2022; Kopp et al., 2021; F. Liu & Zuo, 2011; Lubars & Tan, 2019; Ulfert et al., 2022). For example, machines may excel at some tasks but struggle at others. In addition, beyond the automation capability, some tasks should arguably not be automated to prevent lethal consequences. Moreover, the expense of designing and developing ASs would rise if a specified function was assigned to them. Conversely, if the task is performed by a human, the cost of training should not be overlooked (F. Liu & Zuo, 2011).

1) The Capabilities of ASs and Human

As the LoA increases, there is a shift in the agency of task processing from workers to technology, leading to fundamental transformations in the modern workplace (Parker & Grote, 2022; Ulfert et al., 2022). However, determining which tasks are best suited for human workers versus ASs can be challenging (Figure 2.5). The capabilities of both humans and robots may vary depending on changing contextual factors (Bradshaw et al., 2013). There may be situations where neither humans nor machines can complete a task alone, requiring collaboration (Lakhmani et al., 2020). Such an understanding will also help to design systems that can adapt to new demands and improve performance (C. Liu et al., 2015). In this regard, it is vital to clearly understand the strengths of humans and machines and take advantage of them to facilitate effective collaboration (Grahn et al., 2018). Table 2.2 highlights their strengths.

The core of humans strength is to cope with uncertainty. Humans can adapt to changed circumstances, making them flexible, and this performance is not quantifiable. According to Jason Smith (2020), the task processes susceptible to replacement by smart machines necessitate an intuitive, embodied,



[Figure 2.5 Perspective of early research in adaptive allocation and adjustable autonomy (Bradshaw et al., 2017)]

Human capabilities	Robot capabilities
• Flexibility (Bruno & Antonelli, 2018; Grahn et al., 2018; Ore et al., 2017) • Perception (Bradshaw et al., 2017; Grahn et al., 2018; Krüger et al., 2009) • Sensorimotor abilities (Bruno & Antonelli, 2018; Krüger et al., 2009) • Dexterity: Handling of soft and moving components (Grahn et al., 2018) • Action and movement planning (ability to improvise) (Bradshaw et al., 2017)	• Non-competitive: being void of competitiveness (Welge & Hassenzahl, 2016) • Unconditional submission (Welge & Hassenzahl, 2016) • Self-contained (Welge & Hassenzahl, 2016) • Not taking things personally (Welge & Hassenzahl, 2016) • Assuming responsibility (Welge & Hassenzahl, 2016) • Endurance (Endless patience) (Krüger et al., 2009; Ore et al., 2017; Welge & Hassenzahl, 2016) • Power(Bradshaw et al., 2017; Bruno & Antonelli, 2018; Grahn et al., 2018; Ore et al., 2017) • Reproducibility (Bradshaw et al., 2017; Grahn et al., 2018) • Precision (Bruno & Antonelli, 2018; Ore et al., 2017) • Speed (except in collaboration mode) (Bradshaw et al., 2017; Grahn et al., 2018)

[Table 2.2: The overview of strengths of human and robot] and socially mediated knowledge or skill that even the most advanced machine-learning programs cannot replicate. Moreover, with flexibility and improvised action, humans can deal with solving unexpected problems, resulting in the responsibility for the consequences. Therefore, humans are more suitable for taking responsibility and decision-making than robots in uncertain situations.

On the other hand, automation has some strengths that make it suitable for specific tasks through precise commands. It is non-competitive, unconditionally submissive, self-contained, and assuming responsibility (Welge & Hassenzahl, 2016). In addition, it exhibits endurance, power, reproducibility, precision, and speed, leading that most work results are quantitatively measurable. These strengths help humans by performing human 3d – dangerous, dull, or dirty – tasks (Engelberger, 1983) with no human error. In addition, as robots perform 3d tasks, humans can have more free time for other tasks or personal development. Therefore, agents and robots are suited for tasks that fit with the three d's requiring precision and reproduction capability.

One interesting point from one of the robot's strengths is "assuming responsibility" (Welge & Hassenzahl, 2016). Although the robot cannot take full responsibility, it can take responsibility in some aspects by giving pertinent alarms to notice important information to humans. For example, it can nudge humans to work out and notice the alarm through the connected phone when something goes wrong in the house. Of course, fixing the errors received from the robot will be done by a human, but at least the robot can be an assistant taking passive responsibility.

2) Human Preferences

In the decision on which tasks to delegate, capabilities are not only the only consideration; human preferences influence the decision. Even though automation's capabilities reach an implementable level, aspects of human preferences are significant indicators in task delegation (Gil et al., 2020; Hopko et al., 2022; Kopp et al., 2021; Lubars & Tan, 2019; Ulfert et al., 2022). Humans tend to prefer designs where humans play the leading role than full AI automation (Lubars & Tan, 2019) in measuring the degree of delegation (Table 2.4). Thus, four factors can be considered in human preferences from the framework of task delegability (Lubars & Tan, 2019) (Table 2.3): motivation, difficulty, risk, and trust.

Motivation

Lubar & Tan (2019) present motivation as one of the human preferences to consider, as motivation is important to complete the task with responsibility. In this category, intrinsic motivation, goals, and utility were identified. As an energizing feature, motivation aids in the initiation, maintenance, and regulation of task-related actions by focusing our attention to goals or values (Locke, 2000; Lubars & Tan, 2019). In addition, a task's expected utility captures its value from a logical cost-benefit analysis standpoint. Moreover, motivation is one of the influential factors of human performance (Gil et al., 2020).

Difficulty

Difficulty can be defined as the relationship between the demands of a task and an individual's capability to fulfill those demands, which serves as a subjective indicator of the cost associated with task performance (Lubars & Tan, 2019). The difficulty results from the requirement of time, dedication, specialized abilities, or expertise. HCI research has found that a gap between the user's required and actual technological skills, and system complexity can contribute to technostress (Ragu-Nathan et al., 2008; Ulfert et al., 2022).

Human Preference Factors		Description
Motivation	Intrinsic Motivation	"I would feel motivated to perform this task, even without needing to; for example, it is fun, interesting, or meaningful to me."
	Goals	"I am interested in learning how to master this task, not just in completing the task."
	Utility	"I consider this task especially valuable or important; I would feel committed to completing this task because of the value it adds to my life or the lives of others."
Difficulty	Social skills	"This task requires social skills to complete."
	Creativity	"This task requires creativity to complete."
	Effort	"This task requires a great deal of time or effort to complete."
	Expertise	"It takes significant training or expertise to be qualified for this task."
	(Perceived) Human ability	"I am confident in [my own/a qualified person's] ability to complete this task."
Risk	Accountability	"In the case of mistakes or failure on this task, someone needs to be held accountable."
	Uncertainty	"A complex or unpredictable environment/situation is likely to cause this task to fail."
	Impact	"Failure would result in a substantial negative impact on it adds to my life or the lives of others"
Trust	(Perceived) Machine ability	"I trust the system's ability to complete the task reliably."
	Interpretability	"Understanding the reasons behind the AI agent's actions is important for me to trust the system on this task (e.g., explanations are necessary)."
	Value alignment	"I trust the system's actions to protect my interests and align with my values for this task."

[Table 2.3: A Framework for Task Delegability with AI (Lubars & Tan, 2019, pp. 3–4)]

Risk

When making decisions about delegating tasks in the real world as there is often uncertainty and risk involved; thus, Lubar & Tan (2019) framed three components: accountability, uncertainty, and impact. Beer et al. (2014) stated that task criticality and accountability should guide designers in removing autonomy. In 'Impact', the consequences of the errors can be considered to what extent critically impact on human's life. In many cases, failures or errors at early stages of automation are not as critical as errors at later stages of automation(Beer et al., 2014). The impact may also be relevant to workers' fear of job loss and anxiety about delegating tasks to ASs (Kopp et al., 2021; Saadati et al., 2022).

Trust

Trust in automation's capability is essential in deciding whether to use automation (Castelfranchi & Falcone, 1998), which has been researched intensively over the past several decades and is considered a key element in human-technology relationships. Lubars & Tan (2019) referred to the components of trust from Lee & See (2004) - performance, process, or purpose - in the framework and found that trust was most correlated with human preferences for automation. In addition, Hoff and Bashir (2015) presented a model of factors influencing trust in automation based on a review of 127 empirical studies and distinguished trust with three layers; dispositional trust, situational trust, and initially learned trust. Moreover, potential negative consequences due to technical flaws may cause anxiety for users of such systems (Bertrandias et al., 2021). Therefore, the design of ASs should ensure that users can understand the decisions and behavior of the system to increase trust, such as giving relevant feedback and feedforward mechanisms (Gil et al., 2020).

No AI assistance	the person does the task entirely on their own	"Human only"
The human leads and the AI assists	The person does the task mostly on their own, but the AI offers recommendations or helps when appropriate (e.g., human gets stuck or AI sees possible mistakes)	"Machine in the loop"
The AI leads and the human assists	the AI performs the task, but asks the person for suggestions/ confirmation when appropriate	"Human in the loop"
Full AI automation	decisions and actions are made automatically by the AI once the task is assigned; no human involvement	"AI only"

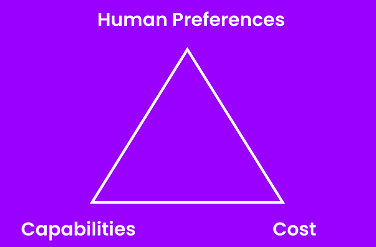
[Table 2.4: degree of delegation (Lubars & Tan, 2019, p. 4)]

3) Cost

Even if the capabilities and human preferences are met, cost represents another key challenge in applying automation in the real world. Bertrandias et al. (2021) stated that it is efficient to delegate tasks if the benefits of delegation exceed its costs. Dearden et al. (2000) highlighted the importance of evaluating the trade-off between benefits and costs from the usage in ASs when making optimal resource allocation decisions. Kopp et al. (2021) found that constant operational expenses are more significant than the initial acquisition and maintenance costs. Nevertheless, individuals will be reluctant to delegate if the anticipated "costs" exceed the anticipated benefits. The attribution of value-added to the human operator and the ASs is fuzzy in joint human-cobot teams, and total costs exceed the one-time acquisition costs of the system itself (Kopp et al., 2021).

2.3.3. Takeaways

- Delegation is a process by which a person transfers responsibility for a task or decision to another person, groups, and machines.
- Capabilities, human preference, and costs (Figure 2.5) are essential aspects in considering which tasks can be delegated to a robot.



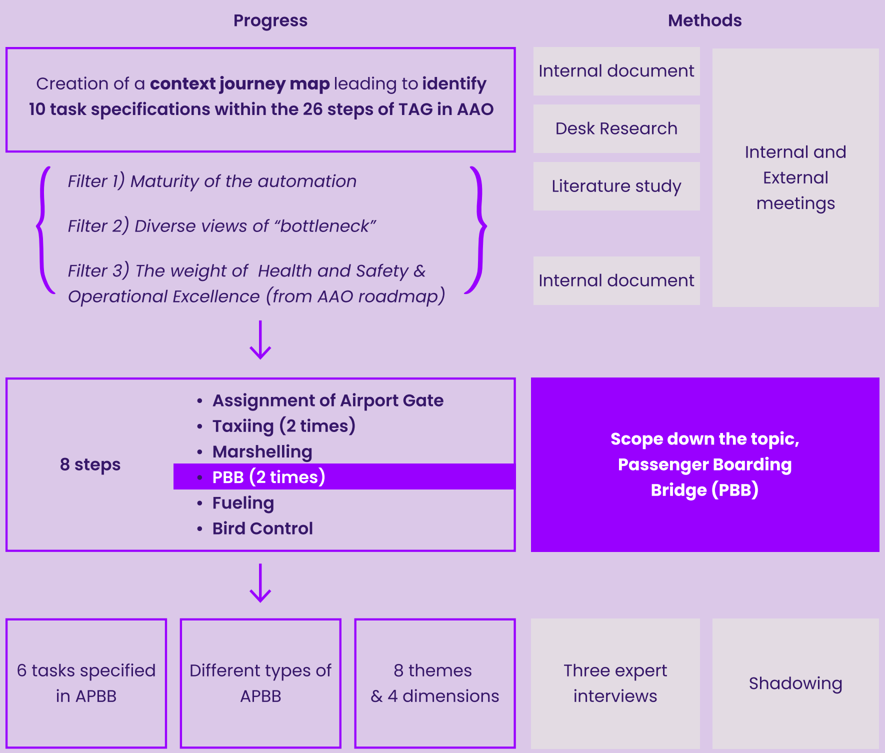
[Figure 2.5. Three aspects that may influence the decision-making of task delegation]

- As for the capabilities, while automation suits consistent and precise performance, humans can better cope with unexpected situations flexibly.
- Humans are more suitable to take responsibility for decision-making due to uncertain situations than robots.
- Although the robot cannot take full responsibility, it can take responsibility in some aspects by giving pertinent alarms to notice important information to humans.
- Despite the full automation capabilities, humans prefer to take the control lead.
- The framework for task delegability with AI will be used to frame the primary research further.
- A trade-off experience between costs and benefits is indispensible in task delegation.

3. Context Research

Context research was conducted based on empirical research to understand the context of AAO in the airport and to scope down the focus. Figure 3.1 shows the overview of the progress. Given restricted airside access and limited schedules, contextual understanding was acquired indirectly through desk research, internal interviews, and internal documents.

As a result, the AAO journey map was created with twenty-six steps and 10 task specifications in AAO. These steps and tasks were scoped down regarding the maturity of the automation in implementation and the AAO roadmap, resulting in a specific scope, Passenger Boarding Bridge (PBB).



[Figure 3.1 Context research overview]

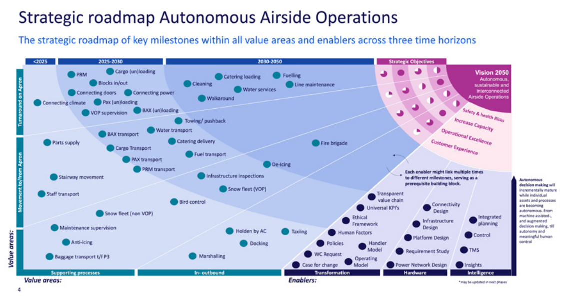
3.1. AAO Context Journey map

Why

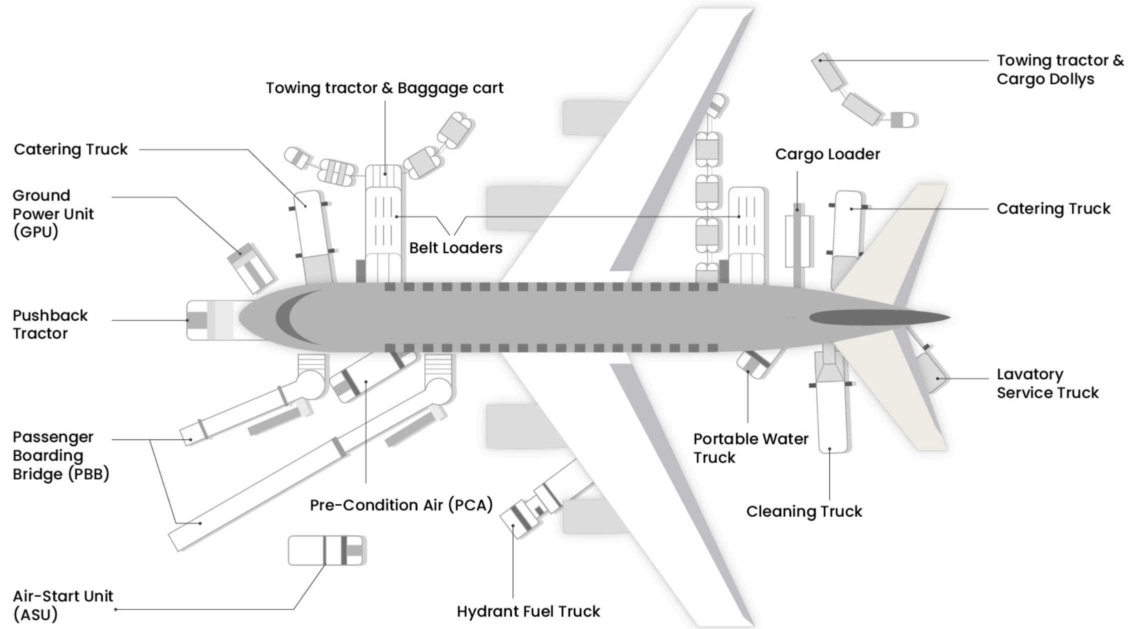
Beyond the vision 2050, RSG seeks to have an overview of AAO in terms of automation and human behaviors. Developing a comprehensive AAO journey map facilitates a holistic comprehension of the entire AAO process. Therefore, before diving into a specific context to choose, the overall AAO journey map was created (refer to Figure 3.3 on the following page).

What

The initial draft was created based on the website "A Guide to Airport Ramp Operations, Ground Handling & Ground Support Equipment (GSE)" (Team, 2020), internal documents from RSG (i.e., the Strategic Roadmap AAO (Figure 3.2) and the RSG CONOPS (confidential)). The website enabled to understand the general Turn around process (Figure 3.A) with specific pieces of equipment involved and workers' main activities in the aviation industry. The details were further validated through internal open-ended question interviews within the Innovation Hub.



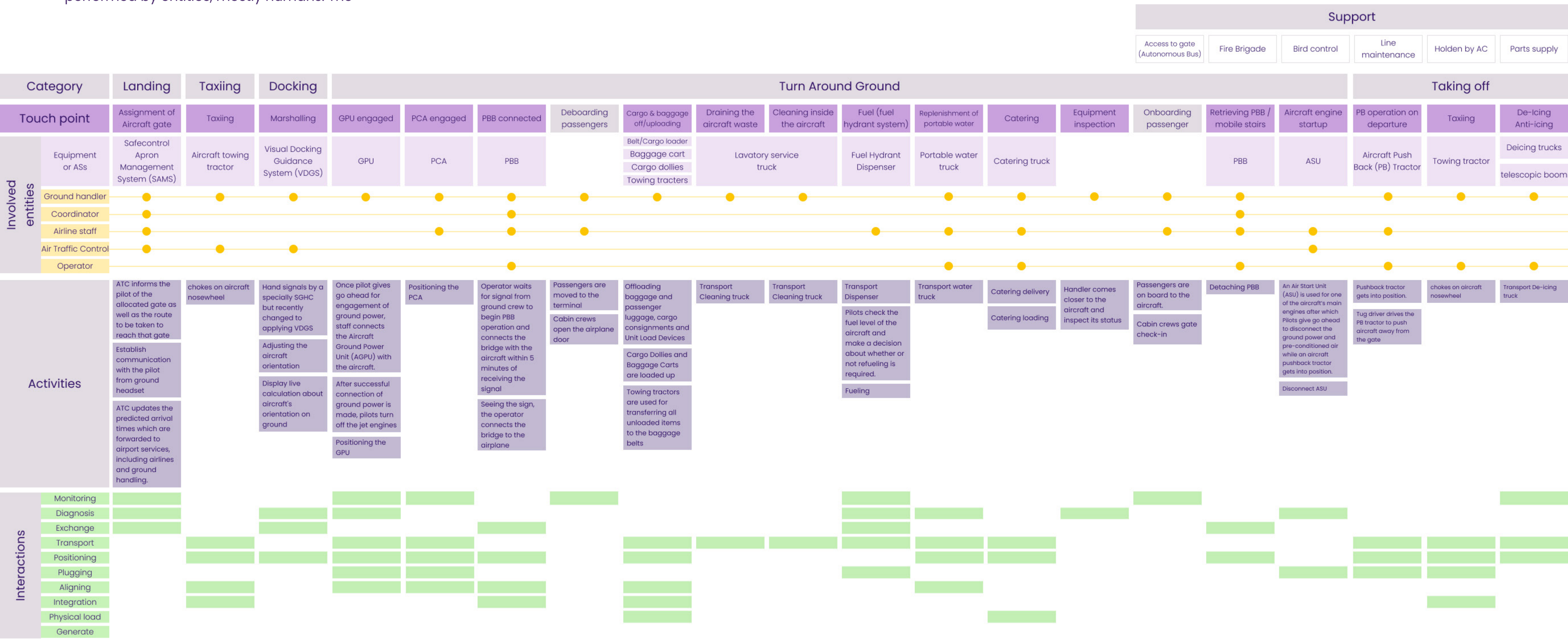
[Figure 3.2: Strategic roadmap AAO (Kotey, R., internal meeting, February 14, 2023)]



[Figure 3.A Turn Around Ground Procedure]

The AAO journey map (Figure 3.3) was developed inspired by User journey mapping (Stickdorn & Schneider, 2021), which is visualizing a user flow to organize user interactions over the journey. The AAO journey map encompasses the complete Turn around process, starting from the aircraft's preparation for landing and extending to the subsequent preparations for the next flight. Within the context of Schiphol Airport AAO, the journey consists of 26 operational steps. Each step includes a description of the involved entities (i.e., equipment or ASs, humans), activities, and interactions. The descriptions of activities highlight the sequential tasks performed by entities, mostly humans. The

Based on the descriptions, 10 tasks that could indicate interactions between humans and machines (or robots) were extracted: **monitoring, diagnosis, information exchange, transport, positioning, plugging, aligning, integration (e.g., connect), physical load (e.g., pull, push, move, hold), generate.** The terms used in the interaction section were benchmarked from the task specifications (Onnasch & Roesler, 2021), and four tasks - **plugging, aligning, integration, and generate** - were added to align with the AAO context.



[Figure 3.3: AAO journey map]

3.2. Decision on the scope:

The three aspects define the scope, the task delegation between operators and the automated system in Passenger Boarding Bridge (PBB) from the perspective of decision-makers.

First, the maturity of automation plays a crucial role in determining the scope, based on Figure 2.1 (pg.17 on Chapter 2) differentiating the types of automation. Internal meetings of the IH assessed the maturity degree to which technology was implemented at each Turn around stage, since each Turn around stage has different maturity of automation implemented. Moreover, for the research feasibility, I opted to study one existing AS in the airside. Thus, Figure 2.1 enabled to discuss the different types of automation implemented within the airport and filter of 26 steps into eight steps (comprising six different activities) in AAO that involve some ASs as seen in Figure 3.4: Assignment of the gate, Taxiing, Marshalling, connection of Passenger Boarding Bridge (PBB), Fueling, and Bird control.

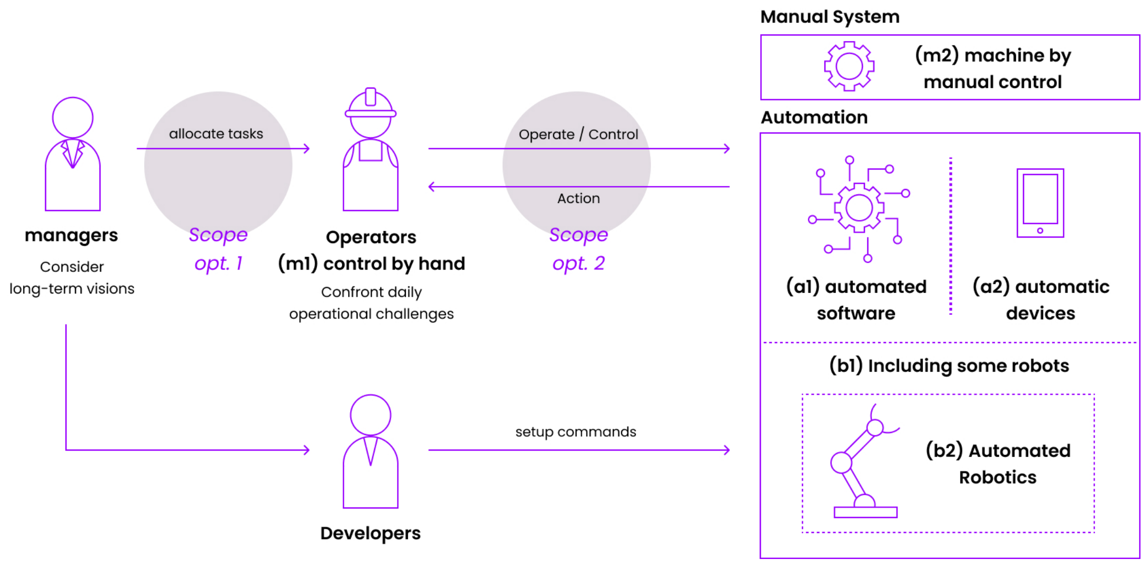
Second, regarding task delegation, there were different views of "bottleneck" or priority within RSG. The managerial level takes long-term visions into account in planning the AS implemented. In contrast, the operators, who take the actual responsibility to operate the AS, might likely focus on their daily operational challenges. Given the limited schedule of the project, the research selected one specific aspect, the managerial aspect as scope option 1 in Figure 3.5.

Category	Steps	Health and Safety	Operational Excellence	Sum	maturity of the automation
Landing	**Assignment of Airport gate**	2	4	6	m2+a1
Taxiing	**Taxiing**	2	3	5	m2+a2
Docking	**marsheller/ VGDS**	2	3	5	m1+m2+(a1)
Turn Around	GPU engaged	2	3	5	m1
	PCA engage	2	3	5	m1
	Connecting PBB	4	4	8	m2+a2
	Deboarding passengers	2	3	5	m1
	Cargo & baggage off/uploading	4	4	8	m1+m2
	Cleaning (Draining the aircraft waste)	2	4	6	m1+m2
	Cleaning inside the aircraft	2	4	6	m1+m2
	Fuel (fuel hydrant system)	2	4	6	m1+m2(or+a1)
	Replenishment of portable water	4	3	7	m1+m2
	Replenishment of meals (Catering)	4	3	7	m1+m2
	Equipment inspection	2	3	5	m1
	onboarding passenger	2	3	5	m1
	Retrieving PBB or mobile stairs	4	4	8	m2+a2
	Aircraft engine startup	2	3	5	m2
Taking off	PB operation on departure	4	3	7	m2
	Taxiing	2	3	5	m2+a2
	De-Icing	2	3	5	m2
Support	Access to gate (Autonomous Bus)	4	3	7	m2
	FireBrigade	2	3	5	m2
	Bird control	2	3	5	m2+a1
	Line maintenance	2	4	6	m2
	Holden by AC	2	3	5	m2
	Parts supply	4	3	7	m1+m2

[Figure 3.4: Eight steps filtered by the maturity of automation]

Passenger Boarding Bridge (PBB)

Lastly, the weight of Health and Safety and Operational excellence in the internal document (Figure 3.2) were considered for additional criteria.The weight referenced the value divided by 4 weights in the pie chart. Among the steps, "connect Passenger Boarding Bridge" showed the highest weight (See Figure 3.4).



[Figure 3.5: Two different views of task delegation depending on scope]

3.3. Expert interviews

Why

Despite the holistic understanding of the AAO journey, detailed operation information about PBB was needed to have consolidated plans for further research. Expert interviews provides background knowledge about the technology and experience in PBB operation, such as how operators work with the Manual PBB (MPBB) and the Automatic PBB (APBB).

3.3.1. Method

Participants

Three experts (P1-P3) with background knowledge about PBB or/and APBB participated in the interviews. The profile of the participants can be found in Table 3.1. The participants' median age is 38 years old, and their median experience is 15 years.

Tool and procedure

Participants were invited to online interviews conducted in a semi-structured format with open-ended questions. Each interview lasted around 30 minutes, and consent was obtained from participants before starting. The entire conversation was recorded on video and audio for transcription purposes.

The overview of the questions (See the detailed protocols in Appendix A):

- Experience in the context and technology of APBB/PBB
- Perception on APBB/PBB (i.e., Negative or positive, benefits/concerns)
- Current constraints (i.e., circumstances and reasons for failures) of APBB/PBB
- Current countermeasure of APBB/PBB (when the failure occurs)

No.	Description	Work Experience (yrs)	Age	Gender
P1	Asset Manager with MPBB operation experience	1-5	19-24	Male
P2	Asset Manager implementing APBB technology	16-20	35-44	Male
P3	Airport Business Unit Director, APBB suppliers company	16-20	35-44	Male

[Table 3.1. The demographic of Participants]

Data analysis

To analyze the data, the interviews were video recorded and transcribed. The data was processed with Reflexive Thematic Analysis (RTA) (Braun & Clarke, 2021) since the approach is more suitable in limited time and relatively small samples than the Grounded Theory. As a result, Reflexive themes were created. The transcript was coded with open coding and clustered to identify common themes. The progress of clustring themes can be found in Appendix B.

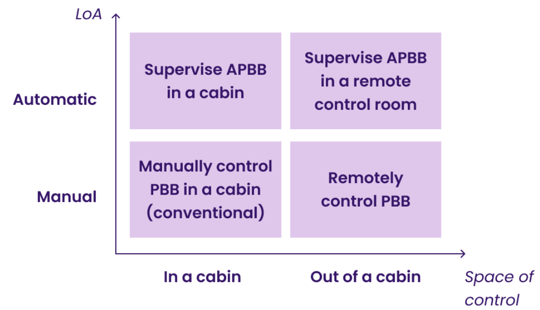
3.3.2. Results

The interviews provided valuable insights. First, the context of APBB operation was identified with a comprehensive understanding. Second, eight themes clustered with four dimensions were identified.

1) The context of APBB/PBB:

6 steps of tasks in operating APBB/PBB

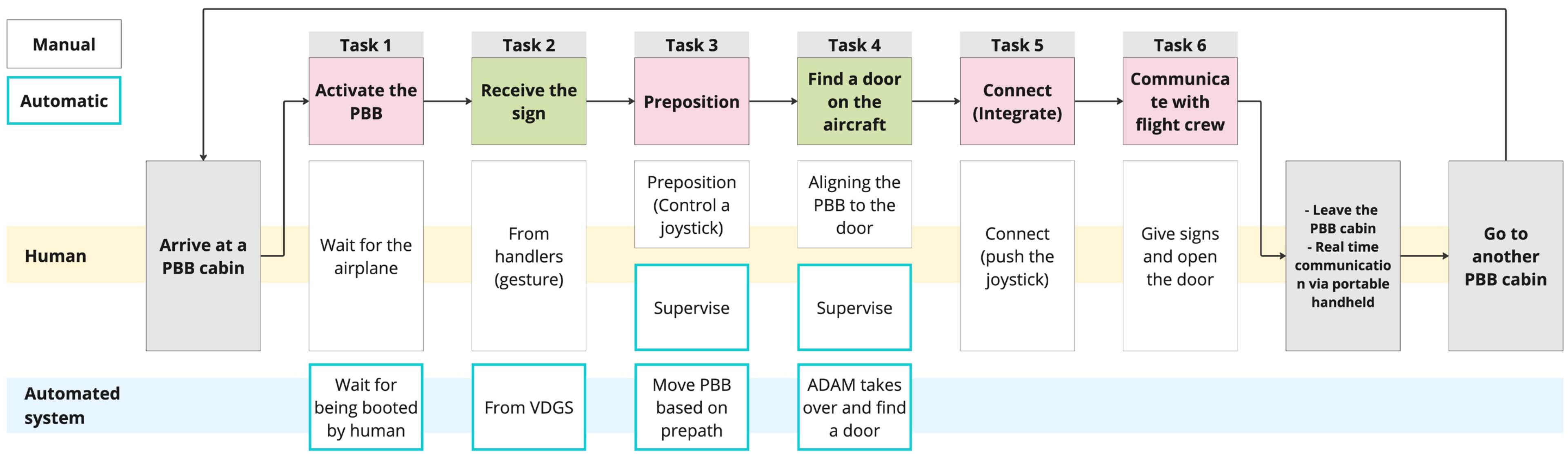
In AAS, there is one APBB in place, while the rest are manually controlled. Both are controlled in PBB PBBs by humans. Figure 3.6 shows PBB and APBB's task flows, defining six tasks based on the interviews. In operating APBB, an operator stands in the PBB PBB to start the system and supervises how automated systems work. When errors are detected, the operators can press the deadman switch button for an emergency stop. On the contrary, MPBBs are fully controlled by operators with joysticks. According to the aircraft types, the height and door location varies, and operators must understand the different conditions.
In the MPBB, P2 said that 50% of errors were attributed to humans, leading to the strong motivation to build APBB.



[Figure 3.7: PBB types regarding automation]

Two different types of APBB - Automatic control in remote control desk or in the PBBs

Apart from the current systems in the Schiphol Airport, there is a full automatic PBB in a remote control desk, which P3 introduced. In this case, operators can control the PBB in a remote control room, while the current system in Schiphol needs operators to be in the PBB PBB. These led to distinctly different types of PBB (Figure 3.7). This can enormously reduce the time duration and human effort to get to the PBBs resulting in more efficient mobility circulation of operators. Nevertheless, P3 highlighted that, in the Europe area, safety approval is essential to realize full automatic operation without operators in the PBB PBB despite capability.



[Figure 3.6. Task flows of PBB/APBB operation]

2) 8 themes and four dimensions (Figure 3.8)

[Figure 3.8. 8 themes with four dimensions in operating PBB/APBB]

Perception on automation	Degree of trust in automation	Improved time efficiency with APBBs
Working condition	Empowerment for operators	Frustration of failures
Causes of APBB errors	Technical sensor issues	Weather distractions
Performance consistency	Different levels of proficiency	Different levles of difficulty

All participants showed **a relatively positive perception on APBB**. As the automation technology of APBB in Schiphol has already been developed with a high success rate (99.3%), they expressed fairly high trust in automation. They believe that APBB can increase time-efficiency. P1 stated, "I do not really have concerns about automatic connection." P2 and P3 also emphasized the full capability of the system.

However, P1, who only has a direct operational experience among the participants, expressed concern about being replaced by the systems, while the other two participants (P2, P3) were concerned about implementation limitations. Whereas P1 described, "OK, I'm getting replaced by an automatic connection, and I don't have to be there anymore", P3 mentioned that operators felt more comfortable using the system because their waiting time for connection was reduced.

> *"The only concern I have is that we are going too slow to implement it (automatic) on every PBB. - P2"*

In operating PBB, **both pride and frustration** were noticed.

> *"Proud that I was able to operate the boarding bridge at an airport such as Schiphol ... on the other hand, was almost terrified because, you know, it is such a big construction and it can make a lot of damage. And you have to do it well, you know, passengers going through it every day. So it also comes with a kind of big responsibility. - P1"*

Time pressure can be one of the critical issues of human errors. P1 and P3 emphasized that as operators tend to be rushed, which can lead to mistakes, delays, or even aircraft damage. In contrast, in the context of APBB, P2 mentioned that the waiting time for the aircraft and the lack of specific tasks to perform can create a sense of boredom.

Operators in MPBB need training for two days, whereas it takes 5 minutes to train how to operate APBB. Since APBB automatically connects the bridge itself, operators only press a button to activate the system. According to P1 and P2, a recurrent training program to operate MPBB has been done for handlers every two years to empower them and prevent the degradation of their skills. However, the one for APBB is being developed and not yet specified.

All participants mentioned **adverse weather** as a constraint for both APBB and PBB. In APBB, heavy rains or fog may decrease the **functionality of camera sensors.** In addition to that, in the remote control situation, obstacles surrounding airplanes may be a problem, so operators may need to have additional communication with handlers below the apron. On the contrary, operators also get distracted in operating MPBB in heavy rains or snow.

> *"the only thing that might distract you sometimes is the weather. If it is raining really hard or snowing or it is windy, ..., you might experience some distractions. - P1"*

Performance consistency was found to be an important consideration in PBB operation, which can vary between the proficiency of operators and difficulty in controlling PBB. P1 stated that more experienced operators performed better. Reducing human error requires more experience. In addition, P1 said that depending on the handler companies, operators are allocated to complete different tasks or to complete "mono-task a day."

In addition, regardless of APBB or MPBB, there are diverse types and specifications, making it difficult for the operator to adapt to control and may influence the operator's performance. P1 stated, "Some bridges are more difficult than others because they are in a certain position and the aircraft in a certain position."

3.3.3. Takeaways

- The 6 steps of tasks in operating PBB were defined based on the expert interview, which could be used for shadowing and further research framework.
- In the continuum of level of automation, APBB and PBB could be differentiated by the space of control. This leads to **four different types of PBB from manual, semi-auto, to full automation controlling in remote rooms.**
- **Four dimensions** were clustered: perception on APBB/PBB, performance consistency, causes of APBB errors, and working condition.
    - Three interviewees showed high trust in automation yet have concerns of being replaced due to feeling human useless
    - Human performance in operating PBB may be relatively inconsistent due to time pressure and different aircraft types, while APBB's performance can be more consistent.
    - APBB is capable of full automation either in remote control or in PBB PBBs. However, humans need to supervise the system due to the responsibility of the operation or some errors (e.g., adverse weather).
    - In operating APBB, supervising the system in PBB PBBs seems not to meet their job pride due to less control of the operations (feeling being out of the loop)
- These four themes will help to refine the research question and the main research setup.

3.4. Shadowing

Why

Observing users using the current APBB is essential to further understanding the context. In addition, it helps to validate Figure 3.6. via the observation since collected inputs were not directly from operators.

3.4.1. Method

Participants

One operator operating APBB was recruited based on the flight landing schedule on the day of experimentation. Since entering the airside requires a lot of time and effort and the schedule is often changed quickly, a one-time experience could be observed. A shift manager arranged the meeting schedule for the observation.

Tool and procedure

During the experiment on the airside, the shift manager hosted the observation journey from start to finish. Before the observations began, an operator at the gate of the platform was introduced, and their consent was obtained for video and photo recording. The operator's interaction with the current control panel in the APBB was observed through videos and photographs, and their thoughts were recorded as they freely expressed them during the operation journey. No questions were asked during the operation to avoid interrupting the operator's performance.

3.4.2. Results

The overview of the operator's journey was mapped after the session as seen in Figure 3.9. And, based on Figure 3.6 (the result from expert interviews in Ch.3), the operator's detailed tasks were identified in terms of Sense, Plan, and Act (Beer et al., 2014) as seen in Figure 3.10 (Next page).

While awaiting the arrival of the aircraft at the platform gate, the operator received flight information through a handheld device, including details such as the assigned gate number, arrival time, flight number, aircraft type, and the current stage in the TAG process.

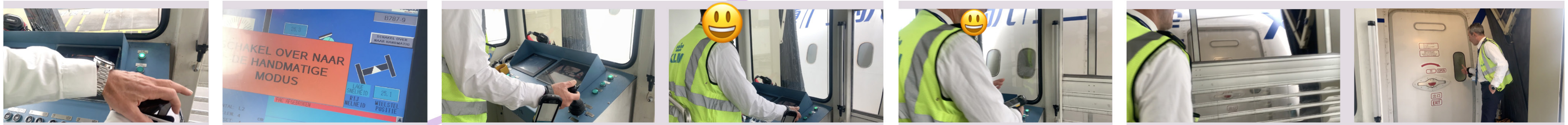
Upon the designated time to proceed towards the PBB cabin, the operator used their security badge to open the doors.

In the corridor, the operator has the responsibility of opening or closing doors to direct passengers along the appropriate route based on dirty or clean flight.

Moving through the bridge corridor, the operator reached the edge of the PBB and accessed the control panel situated at the connection point with the aircraft door.

The operator awaited a signal from a ground handler positioned beneath the aircraft wing on the ground, which was observed through a window.

While waiting for the signal, the operator monitored the control panel, which displayed camera views providing an overview of the surrounding circumstances. When pressing the "start" button, it illuminated a corresponding indicator light but did not initiate immediate movement of the PBB.



Upon receiving the signal from the ground handler, the operator commenced pushing the joystick to initiate the autonomous prepositioning of the PBB (Task 3). However, he had to keep pushing the joystick.

Although an error occurred in the AS during aligning (task 4) the PBB with the aircraft door, the operator showed confidence in taking the control back, as it was a common point of error. He had no clue the causes of the error. But he even phrased, "I like the challenge."

Consequently, the operator regained manual control of the PBB and completed the necessary adjustments.

When he finished connecting PBB, he reported completion via the handheld.

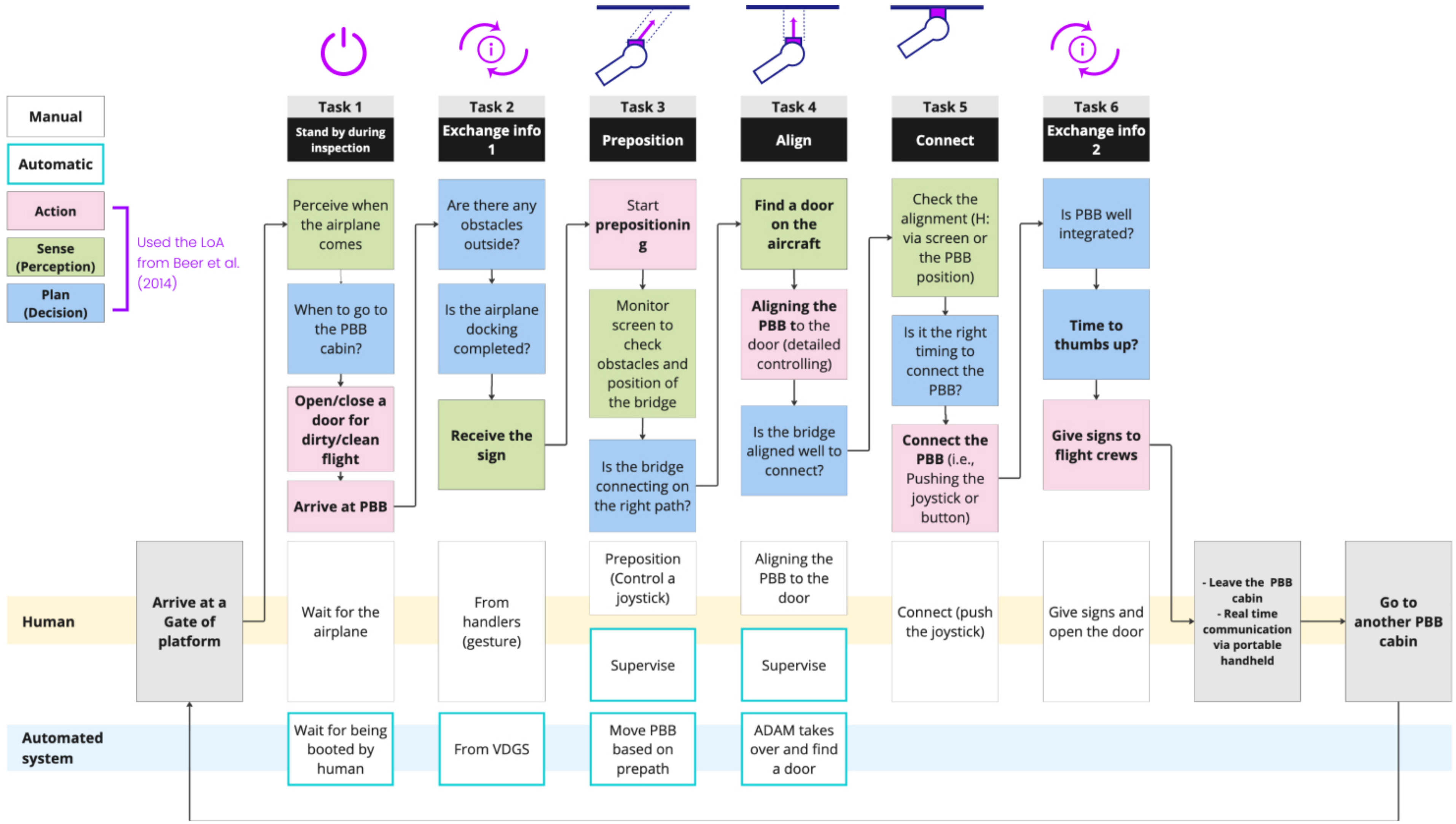
Once the grill gate was opened, the operator approached the aircraft door, knocked on it, and signaled with a thumbs-up gesture, indicating that passengers were allowed to disembark.

[Figure 3.9 APBB operation journey from shadowing]

In the journey, three points were noticeable. First, in task 1 (Activate), operators do not activate (or turn on) the system, but the system is always ready to be controlled by humans. In this stage, operators usually wait for the aircraft at the platform, not in the PBB PBB, due to safety measures, while ground handler inspects the aircraft underneath. Thus, "Stand by during inspection" will be used instead of defining "activate" in task 1 as seen in Figure 3.10.

Secondly, the operator described the responsibility of directing passengers on specific routes based on whether the flights are clean or dirty, while heading towards the control panel in the PBB. The determination of the route depends on the origin of the flight, as different security lines are designated accordingly.

Thirdly, it was observed that the operator demonstrated confidently professionally dealing with APBB's 'manual switching' malfunction. The operator is aware that the recurrent errors occurs occasionally, leading him to be prepared for these situations when he has to regain the control. The participant even expressed confidence, stating, "I like the challenge", although he was unsure about the causes of the error.



* ADAM: The sensor attached to the front door of the PBBs sensing the door location

[Figure 3.10 Task flow of Passenger Boarding Bridge with sense, plan, act]

3.4.3. Takeaways

- The task flow (Figure 3.10) was created with more detailed and specified subtasks in terms of Sense, Plan, and Act, which serves as the fundamental of a probe for the primary research.
- The operator was observed with high professional operating demonstration, dealing with an error smoothly. However, the causes of errors are unclear with only showing "switch to manual." This begs the question of what exactly could be the cause.

Summary of literature study (Ch.2) and context research (Ch.3)

1. Based on the definition of automation and task specification in Chapter 2, tasks and procedures in AAO were specified with the criteria of maturity of the automation leading to the chosen domain among the context of AAO (Ch. 3), **Passenger Boarding Bridge (PBB).**

2. Multiple perspectives should be considered to ensure a holistic understanding of HRI or HRC. In particular **four factors - time and space, levels of autonomy, robot task specification, and team composition** - was zoomed in.

3. Three factors - **human preferences, costs, and capabilities** - can influence task delegation, which impacted the primary research planning.

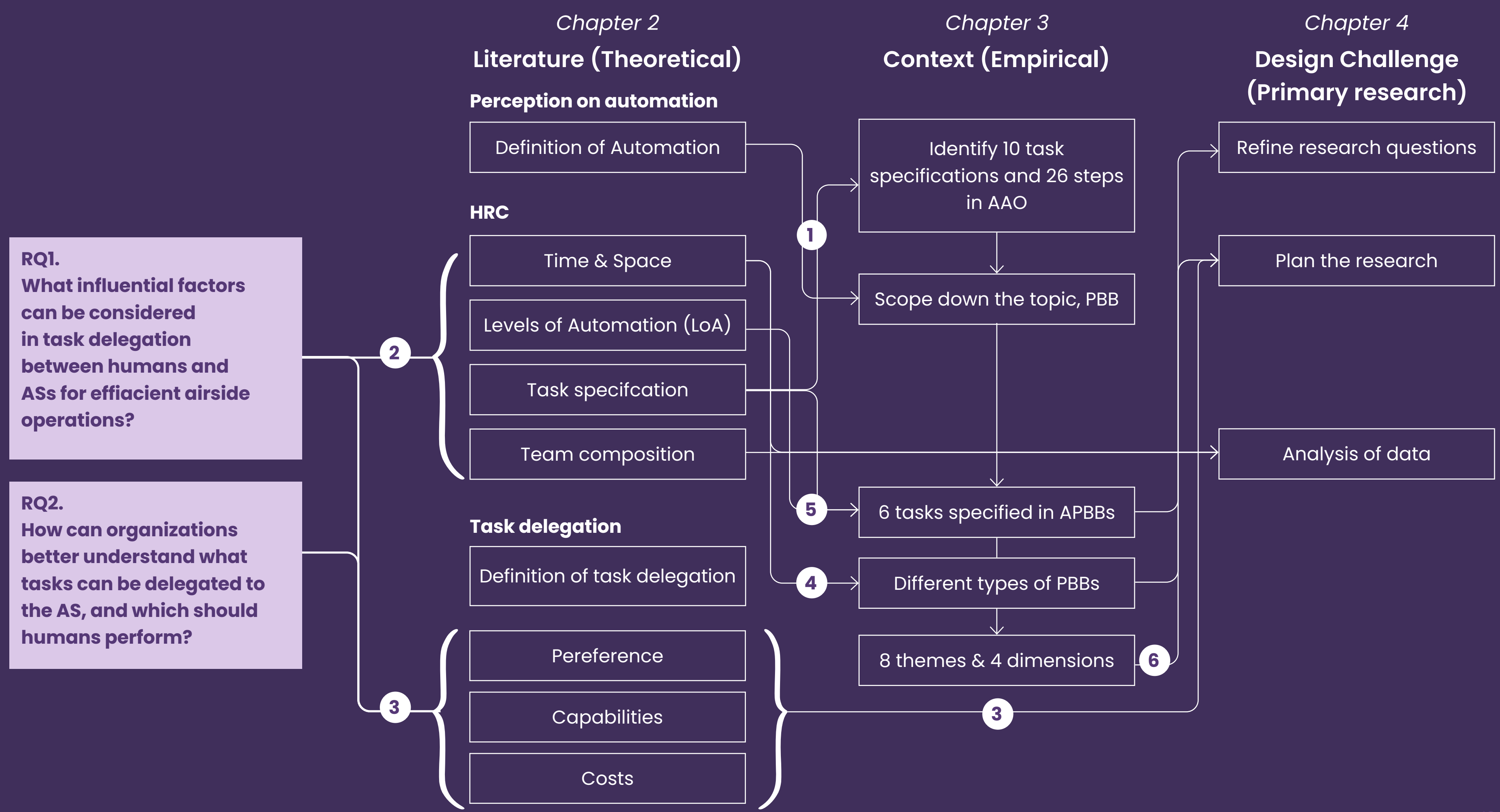
4. The examination of time and space as a HRC factor enabled the identification of **four types of PBBs**, leading to specify further primary research and consequently, a refinement of the research questions.

5. With the LoA, the task flow (Figure 3.10) was created with 6 tasks which was utilized in the primary research as a reseach probe.

6. Four dimensions from the expert interviews (Ch.3) – **perception of APBB/PBB, performance consistency, causes of APBB errors, and working conditions** – help to refine the research questions and the main research setup.

From the literature study, although AS technology has progressed towards full automation, there is a general tendency among humans to prefer retaining control rather than relying solely on ASs. However, the context research indicates that interviewed experts would like to realize full automation.

The implementation of APBB has shown potential in improving work accuracy and efficiency compared to manual operator control, suggesting a potential increase in the adoption of APBB in the future. Despite the possibility of APBB's full automation capabilities in both remote control and PBB PBB, human supervision is required to ensure responsible system operation.



4. Design challenge

In context research (Chapter 3), the PBB was selected as the scope for this research within the AAO. Regarding PBB's task delegation process and the implications from the preliminary study (Chapter 2 and Chapter 3), this chapter defines the core problem, the design goal, and the following design to achieve the goal. Furthermore, to realize the intended objective, a combination of in-depth interviews and a comprehensive survey were carried out.

4.1. Refine research questions

4.1.1. Problem statement

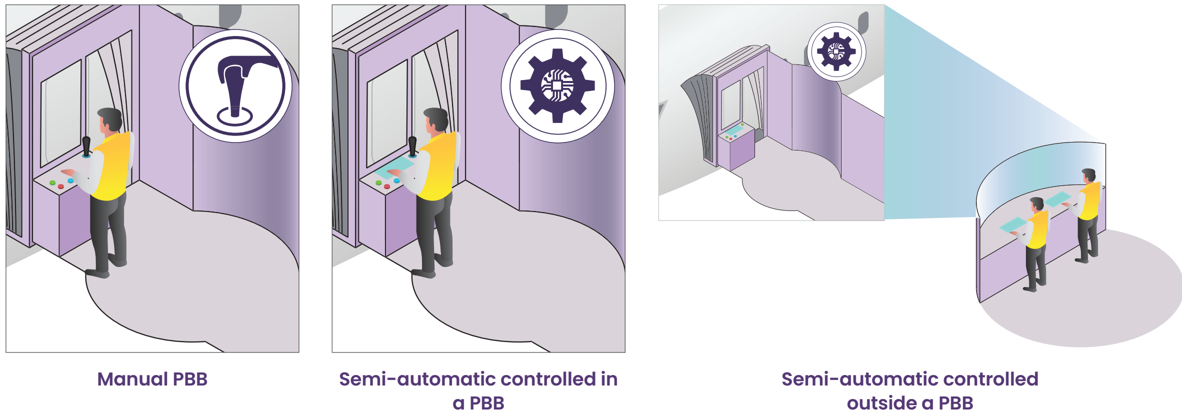
In pursuit of consistently fast and accurate PBB connection performances and better working conditions, stakeholders have shown a positive inclination towards adopting APBBs in practice to delegate certain tasks to ASs. However, concerns about errors in AS raise questions about full automation, prompting various stakeholders to understand the appropriate delegation level to ASs. This transition may require a future vision involving the gradual adoption of various APBB types, with multiple stakeholders, until a complete transition from PBB to APBB is accomplished.

4.1.2. The design goal

The design goal is for organizations to strike a balance between the decision-making authority retained by humans, and that can be transferred to ASs. To achieve the goal, the research question and following sub-questions were reframed as such:

RQ.
In the transition of different PBB operation types (Figure 4.1), how can we better understand which tasks can be delegated to ASs, and which tasks humans should perform?

- SQ 1. How do the influential factors (e.g., human preferences, capabilities) correlate most with each task in the task delegation of APBB? (To look into human factors)
- SQ 2. Are there tensions of perspectives between operators and decision-makers when delegating tasks to the AS in APBB?



[Figure 4.1 Different types of PBB
(left: manual control, middle: semi-automatic controlled in a PBB, right; semi-automatic controlled outside a PBB)]

The SQ1 is formulated to discover correlations between task delegability and the influential factors identified in the literature. Additionally, recognizing the potential divergence in viewpoints between operators and decision-makers, SQ2 was designed to uncover the inherent tensions within the context of Automatic PBB (APBB).

To address these research inquiries, the primary research phase was planned with In-depth interviews and a survey, as elaborated in the subsequent page. This phase seeks to examine the existing operational practices of operators and their challenges in managing APBB/MPBB errors. The empirical insights from this investigation will be merged with a speculative probe, allowing for immersive exploration of conceivable scenarios (illustrated in Table 4.1) concerning the transition across different forms of PBB control. The integration of these insights will ultimately facilitate the creation of a roadmap, mapping the organization's broad direction in the near future.

Description	Current	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Full Automatic control in remote control desk	0	0	0	0	0	100%
Semi-automatic control in remote control desk	0	0	0	50%	100%	0
Automatic control in PBB	0.8%	50%	100%	50%	0	0
Manual control in PBB	99.2%	50%	0	0	0	0

[Table 4.1 Examples of scenarios in applying different PBBs in different levels of autonomy]

4.2. Primary research

Why

The primary research was conducted to

- Discover correlations between the influential factors (e.g., human preferences, capabilities) and task delegation
- Find the spot of tensions in perspectives towards ASs between operators and decision-makers

To do so, In-depth interviews and survey were selected. In-depth interviews are well-suited for gaining insights into individuals' perceptions and experiences (Semi-Structured Qualitative Studies, n.d.), while survey allows to triangulate the interview findings and to discover correlations between the influential factors and task delegation in APBB.

4.2.1. In-depth Interviews

Participants

Six interviews were conducted. Three operators and three decision-makers were recruited with the criteria: 1) Operators who have either MPBB or APBB operation experience, and 2) Decision-makers who have knowledge of APBBs, and influence APPB implementation or development. The median age of the participants is 34.5 years old, and their median work experience is 9.5 years.

The participants were recruited with Snowball sampling (C. Parker et al., 2019). In this method, researchers start with a small number of initial contacts who meet the research criteria and invite them to participate. Agreeable participants are then asked to recommend other contacts who also meet the research criteria and might be willing to participate, and the process continues recursively. In this study, managers at ground handler companies, one of the stakeholders in AAO, were initially contacted through RSG's internal contact lines. With the managers' assistance, participation advertisements were distributed with available time slots, or Agreeable participants were recommended. Additionally, one participant was recruited through LinkedIn by reviewing the profile of a job professional using the keyword "Passenger Boarding Bridge."

No.	Description	Work Experience (yrs)	Age	Gender
O_P1	MPBB operator	1-5	19-24	Male
O_P2	MPBB operator	1-5	19-24	Male
O_P3	PBB/APBB operation trainer	20-	35-44	Male
DM_P1	APBB Engineer	1-5	25-34	Male
DM_P2	Asset Manager implementing APBB technology	20-	45-54	Female
DM_P3	Airport Business Unit Director, APBB suppliers company (same as P3 of the expert interview)	16-20	35-44	Male

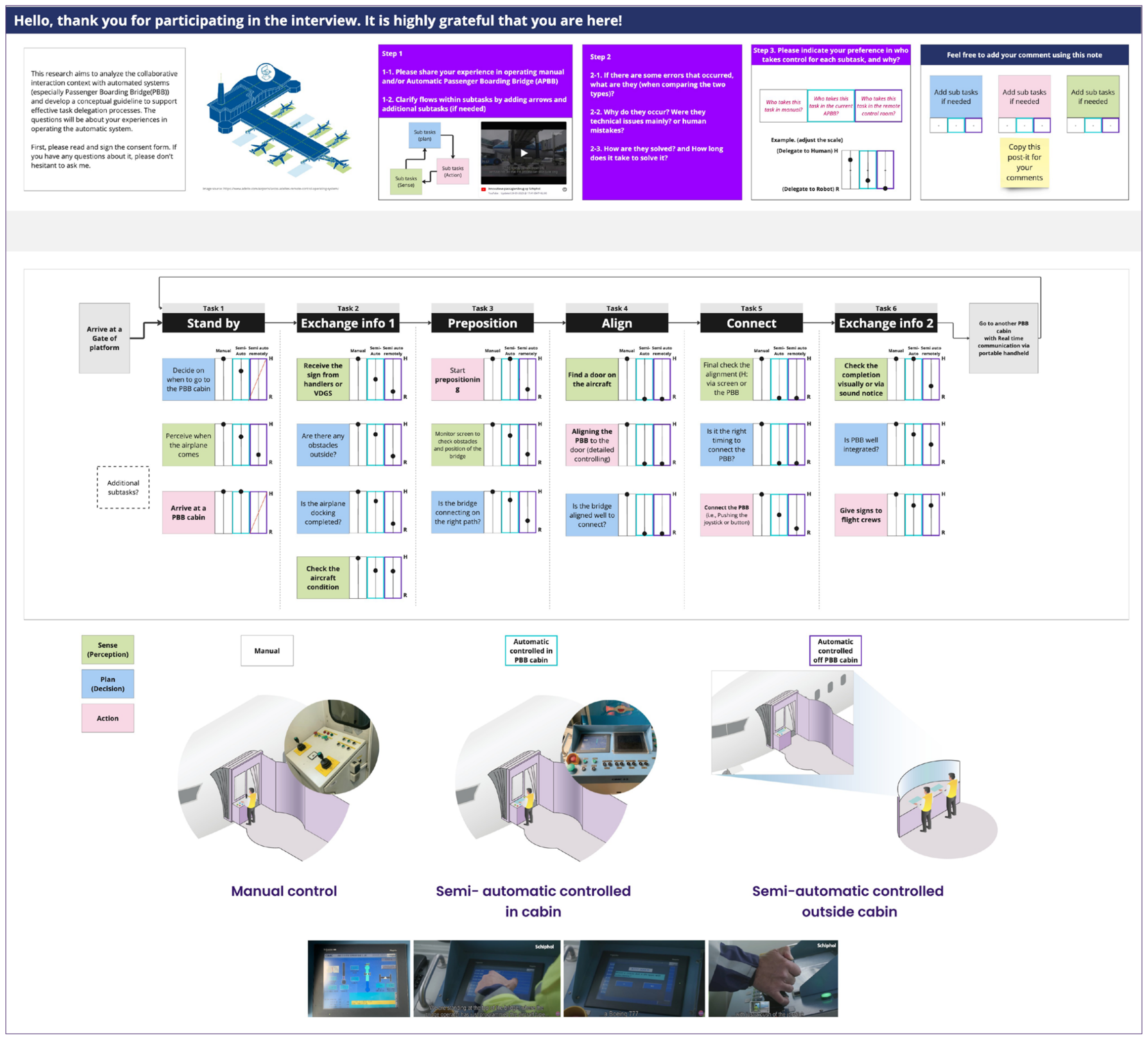
[Table 4.2. Criteria and demographics of participants]

Tools and Procedure

Setup

Sensitizing probe was provided to participants, as seen in Figure 4.2., which helped them explain their tasks more specifically based on the basic task flows of PBB/APBB. Since the interviews were conducted online, it was digitally created with Miroboard (https://miro.com/app/board/uXjVMJorqpM=/) including:

- Task flow of PBB/APBB (6 tasks - standby, exchange information-1, preposition, align, connect, exchange information-2)
- Diagram of different types of PBB (manual, semi-auto, semi-auto in remote control room)
- Pictures of PBBs and control panels



[Figure 4.2. A sensitizing material for interviews]

Protocols

As a semi-structured interview, open-ended questions were provided to participants. The interview started with an introduction, briefing the purposes of the study and asking the participants to fill in the consent form. It includes information about the project objective, procedure, data management, and risks. And then, the participants were asked to introduce themselves shortly and explain their personal experience in operating APBB or PBB. The researcher also showed the task flow of PBB, explaining them shortly, and the main questions were provided to the participants. The interview has the same question format for each of the six main tasks. Depending on the existence of participants' APBB experience, the form of questions was adjusted, aligning with their context. Since MPBB operators lack experience in APBBs, the question includes "would" to ask about their preferences. In each interview, participants were asked to share their PBB experience and to decide to what extent they would delegate a task to ASs to perform the six given tasks. They were also required to explain the reason for saying so. The details of pre-structured questions can be found in Appendix C, but depending on the participants' answers, the questions were rephrased or omitted.

Data analysis

First, the transcriptions were analyzed using RTA (Clarke & Braun, 2014) to explore people's experiences, views, and perceptions (Braun & Clarke, 2013) of ASs in PBB experience. Inductive coding was used to discover empirical insights, primarily utilizing semantic coding with openness for latent coding (Braun & Clarke, 2013).

In the first-round coding, Simultaneous coding was applied with Structural coding and Values coding (Saldaña, 2009). Structural coding involved clustering codes based on task numbers (one to six) relevant to the research question (MacQueen et al., 2008), as well as based on the capabilities and limitations of humans and ASs. In addition, Values coding was used to inductively categorize participants' perceptions into "Attitude," "Believe," and "Value" (MacQueen et al., 2008). Phrases signifying one's own opinions, such as "I think" or "I feel" were also taken into account. Based on the RTA process, transcription-inspired random codes were also generated from scratch and clustered with the researchers' interpretations, combined with the first codes. These clusters enabled to identify a large segment of texts and analyzed the tendency in the degree of delegation by each task. The detailed progress can be found in Appendix D.

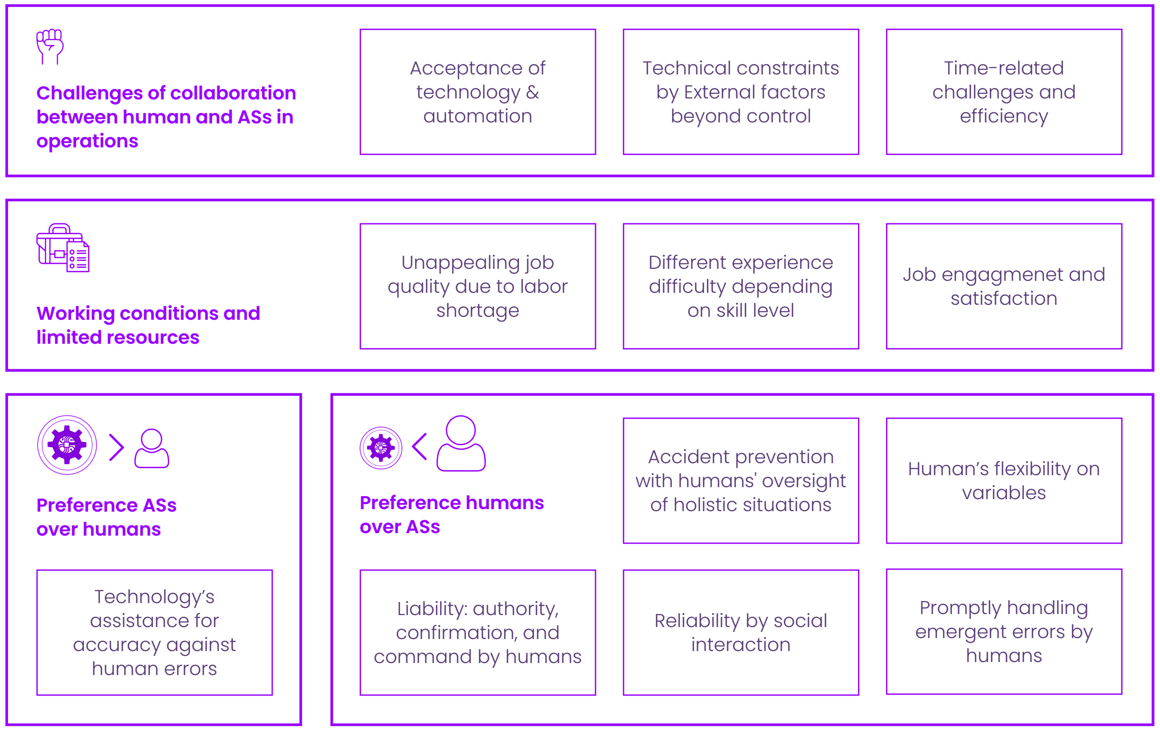
The second analysis utilized Sankey diagrams to explore correlations between tasks and values. Sankey diagrams visually illustrates the movement of values from one group to another.

The third analysis involved the visualization of the perception of task delegability inspired by Beer et al. (2014). With the probe, the participants described their opinions or perceptionson the extent to which each task could be delegated to ASs. While some participants actively engaged with the probe and adjusted the scale accordingly, while others reflected on their experiences and mental simulations without providing direct input. In the latter case, the researcher adjusted the scale based on explicit comments and verified adjustments with the participants. However, it is essential to acknowledge that the researcher's subjectivity in determining scale adjustments might have influenced the overall results. Consequently, the result provides a trend of observed perspectives, both in agreement and divergence, between operators and decision-makers.

Result

1) Themes from RTA

Figure 4.3 presents the 12 themes and 4 aggregated clusters.



[Figure 4.3 12 Themes and 4 dimensions of task delegation]

Challenges of collaboration between human and ASs in operations

Acceptance of Technology & Automation

In general, the acceptance of technology and automation was positive from all participants, although they acknowledged the possibility of automation failures. Moreover, O_P3 mentioned, "Now I can honestly say that it's really well built and it's quite real, but reliable and it's (The automatic connection) fast. So I think (...) automatic connection will be the future." O_P1 and O_P2 also presented a preference to operate PBB with automatic sensors because the old equipment has some trouble controlling.

> *"Handling is more safe because technique is safer. It's more reliable. Of course there will be failures, but I really believe there will be less failures than by humans." - DM_P2*

However, there are some preferences for MPBB. Since full automation may require more resolution time to determine the cause of the problem. In addition, most airports still use MPBB, which may affect the decision on implementation. This may be because particular aircraft is yet only available to MPBB, not APBB.

> *"The manual is, in our opinion, very beneficial in case of any failure." - DM_P1*

Technical constraints by external factors beyond control

Despite the generally positive perceptions of ASs, certain technical constraints were identified by both decision-makers and operators due to unforeseen circumstances. As the APBB operation relies on smart camera systems, camera failures pose a critical challenge to smooth operations. In particular, **environmental conditions** significantly influence the camera performance of ASs.

> *"... if high winds occur ..., then sometimes the trim can let loose of the airframe and if it let loose yeah then it's also an error and the number of bridge malfunction." - O_P1*

DM_P1 identified instances of the system freezing due to scorching temperatures, while both DM_P1 and DM_P2 expressed concerns about the influence of fog and rain on camera functionality. In line with the camera functions, DM_P1 stated that video data transmission could be delayed if APBB was controlled in the remote control room, which might lead to sudden incidents in a second.

Another technical hurdle identified is that ASs provide **limited feedback** about failures without explaining the causes of the error. DM_P2 stated that the asset itself recognized some failures, but not everything was still visible. DM_P1 also highlighted that some errors were difficult to find the cause to resolve, leading to longer resolution time and influencing operations.

> *"We blindly just start from one way to end way, and this is our luck only how many times it will take to resolve the issue." - DM_P1*

Furthermore, uncontrollable factors could cause PBB errors, such as weight shifts, sudden obstacles under the apron, or different parking positions, requiring humans to regain control. For example, O_P1 and DM_P2 identified the situation when people passing by the PBB accidentally touched the rope, then the bridge system shut down immediately, leading to the failure mode. In addition, if the aircraft is parked some centimeters later than the right spot where it has to be, the system recognition of the aircraft type can cause errors. This is because the first meters of the PBB drive to the aircraft on the knowledge that it gets from where it should stop. Moreover, in unloading and loading the airplane, the aircraft weights can shift suddenly, affecting the trim unstable and leading to connection failure.

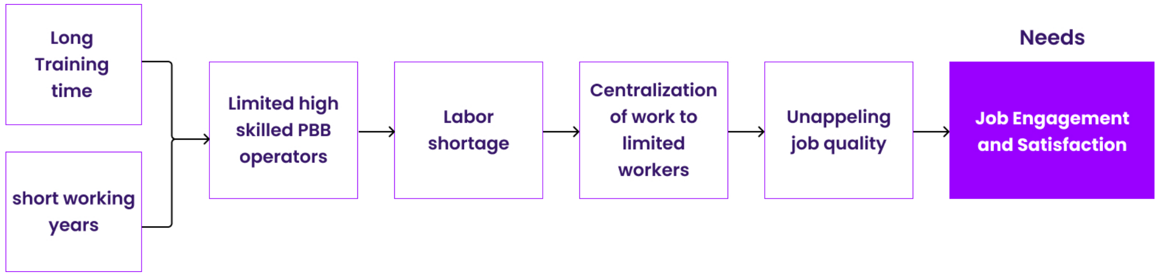
Time-related challenges

Time-related challenges were noted by most participants mentioning "it takes much time." PBB operations are under time pressure. Time efficiency is one of the reasons to start implementing APBB in practice. According to DM_P2 and O_P3, APBB's current connection success rate averages 50 seconds, a time that only experienced operators can reach. Based on the internal test data from 2018, individuals who have just completed the training typically take around 1.5 to 2 minutes or even longer to complete the PBB connection process.

From the decision-maker's perspective, they are likely to take both operations and maintenance time into account, while operators tend to focus on their performance. According to DM P1, resolution time should be within 5 to 10 minutes, but diagnosis within that time remains a current challenge. Even installing the equipment turns out to be challenging as a long procedure is required. DM_P2 identified that at least 6-8 weeks are needed, from removing the old PBBs, to installing a new one, and to finishing tests. On the other hand, for the operators, their performance has to do with "how many bridges they connect in a day and how long they are doing it" (O_P3).

In particular, DM_P1 exhibited a concern that additional resolution time may be needed if the system is fully automated without humans in the PBB. In technical failures of APBB, the operator is then required to physically check the situation and determine the cause of the problem. If the appropriate error clue is missing, the operator "needs to examine the system from A to Z."

Working conditions and limited resources (Figure 4.4)



[Figure 4.4. Correlations of the theme of "Working conditions and limited resources"]

Unappealing job quality due to labor shortage

Acknowledgment of unfavorable working conditions arises from decision-makers and operators who recognize the unappealing nature of their jobs. A prominent factor identified is the labor shortage, resulting in increased job intensity. O_P2 expressed dissatisfaction due to the overwhelming workload, highlighting instances where operators had to handle multiple tasks simultaneously. O_P2 expressed "horrible" when mistakes (e.g., aircraft damage) are made, which may daily occur somewhere in the airport. O_P1 further remarked on the challenging and demanding nature of the work compared to the compensation received, describing it as "not cool" and "very hard."

The scarcity of well-trained PBB operators was specifically mentioned as a significant factor. O_P2 noted that while there is considerable interest in obtaining employment, many employees leave the company before training to operate PBB. Consequently, the accumulation of extensive experience is necessary for proficient PBB operation.

Different experience difficulty depending on skill level

Operators unanimously emphasized that experience level directly correlates with the level of difficulty experienced. O_P1 and O_P2 stated that MPBB control was not a challenging task; however, O_P3 highlighted the different performance levels and time efficiency associated with varying experience levels. Highly experienced operators could connect the bridge within one minute, akin to automatic performance. Conversely, individuals who had recently completed the training required 1.5 to two minutes or longer to accomplish the same task, resulting in inconsistent to connection performance. O_P3 also highlighted that certain airlines required a specific limited connection time, such as within 3 minutes for their quality of service. In this case, more experienced operator is sent to the gate for this airline.

Job Engagement and satisfaction

Job engagement and satisfaction were identified as an important aspect for operators to stay in their work and for organizations to keep their essential human resources and save their training costs. In controlling PBB, both O_P1 and O_P3 described their experience as a "game" and felt "skillful (O_P1)". O_P2 also stated "positive" to control MPBB. Even in imagining the APBB situation, O_P2 is likely to outlook satisfying future by stating, "I think it would be fine and just chill." Furthermore, DM_P3 prospected that if APBB was controlled in a remote room, operators could have more opportunities to have more experience, leading them to feel more motivated and stay in the company for more years than when using the traditional operation.

Preference ASs over humans

Technology's assistance for accuracy against human errors

Both operators and decision makers acknowledged the humans limited abilities in tasks requiring high accuracy. O_P3 and DM_P2 highlighted that the percentage rate of correct connections would be much higher than when humans would, indicating about 1.7x higher average failure rate of APBB than the one of MPBB connection. DM_P2 also emphasized that half of the failure of MPBB is from humans. In particular, in task 4 (align) and task 5 (connect), O_P3 and DM_P2 highlighted the limited ability of humans to accurately measure distances and angles between the bridge and the aircraft using their eyes, whereas ASs can precisely measure them mathematically.

> *"...there will be failures, but I really believe there will be less failures than by humans." DM_P2*

> *"The percentage rate of correct connections (from APBB) will be much higher than when it's done by operators." O_P3*

Preference humans over ASs

Accident prevention with humans' oversight of holistic situations

Interviewees highlighted the importance of human involvement in overseeing critical checks and ensuring safety. O_P1 phrased the overall check of the circumstances in task 2 as "the (most) biggest bottleneck (of ASs)." The handlers under the apron should check for foreign object debris, oil leakage (DM_P1), and/or door damage (O_P1, O_P2) on the aircraft before starting PBB connection. O_P1 further stressed the importance of this step, stating, as DM_P3 acknowledged the need for double-checking with humans in the system for safety reasons.

> *"I think the checks on the outside far more critical than actually connecting the bridge because actually connecting the bridge is not really that difficult for me manually." - O_P1*

Even in the remote control situation, DM_P2 and O_P3 imagined that humans needed to monitor and look into the problem. DM_P2 stated that "Well, I think even from a remote stand that it's still the last check if everything is safe to start driving or connecting even though cameras are, somebody has to look into the camera to make sure..."

Moreover, task 6 (exchange info 2: giving a signal to cabin crews) was also found that the ability of operators to evaluate and make critical judgments based on visual cues remains indispensable for ensuring the safety of passengers and crew. Also, this procedure is done among other departments, such as airlines, so a new agreeable measure is needed.

Liability: Authorization confirmation and command by humans

Liability issue was noted by both decision-makers and operators. Participants would like to have humans have the role of authorization in the final decision, giving a confirmation or command regardless of PBB types. DM_P3 highlighted the role of human decision-making in accepting or denying requests. While certain tasks can be automated, the final decision lies with the human operator, who assesses the situation and determines whether the request aligns with safety protocols. Moreover, participants emphasized the significance of human confirmation in verifying the absence of damages before connecting the PBB. O_P1 highlighted the airline's procedure, where the flight officer is responsible for inspecting the PBB door in task 2. If damages are detected, it is crucial to report them to the airline's technical services.

> *"I think being in a critical situation is always good to supervise or to have someone is saying, yeah, everything is alright. DM_P3"*

> *"You can automatically, you know, connect the boarding bridge. But who's gonna check for damages, and how do you tell the system you're now OK to connect the border bridge? O_P1"*

> *"If you have a camera on the bridge or so you can do a visual inspection by the camera (in a remote room), but then like it's always with liability, O_P2"*

promptly handling emergent errors

The human strength for promptly handling emergent errors was identified. In the case of semi-auto operation within a PBB, DM_P1 emphasized the importance of human supervision in promptly identifying errors and comprehending their causes more quickly than someone elsewhere. In addition, DM_P3 highlighted the necessity of an emergency button, even when the control is remote. O_P1 further emphasized the human capacity to rectify errors that might be overlooked by computers. Operators sometimes take the control back and manually finish the PBB connection in the current APBB.

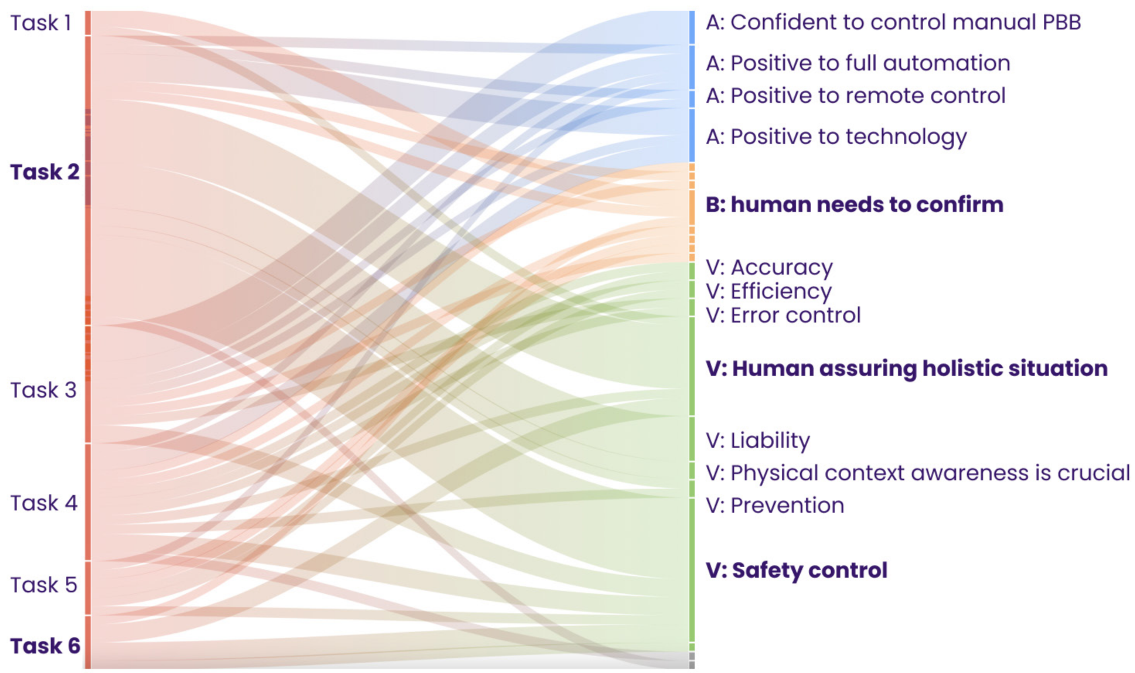
Flexibility on variables

In addition to emergent errors, flexibility for diverse conditions could be critical, such as handling a sudden weight shift. More importantly, different types of aircraft and PBB interface might be challenging for the ASs to self-distinguish and control the operation. Even the ASs to be developed and installed may have many different types from different companies. To have standardized protocols shared internationally should be made for future research.

Reliability by social interaction

Reliability with social interaction is also a noticeable value in operation. Participants emphasized not just the enjoyment of "a small social point of interaction (O_P2, DM_P3)" and being "a somewhat buddy in the bridge (O_P1)" but also reliability. In particular, in tasks 2 and 6, the interactions with ground handlers or cabin crews from different departments are crucial to reassure that everything is fine and avoid bringing "hazardous situations (O_P1)."

2) Sankey diagram between tasks and values



[Figure 4.5. Sankey diagram between 6 tasks and Values coding]

The Sankey diagram (Figure 4.5) provides the overarching relations between tasks and Values codes. Particularly task 2 (i.e., excahnge information) highly relates to the value of "human assuring holistic situation," "liability," "physical context awareness is crucial," and "safety control." These values are relatively correlated to humans' confirmation and command.

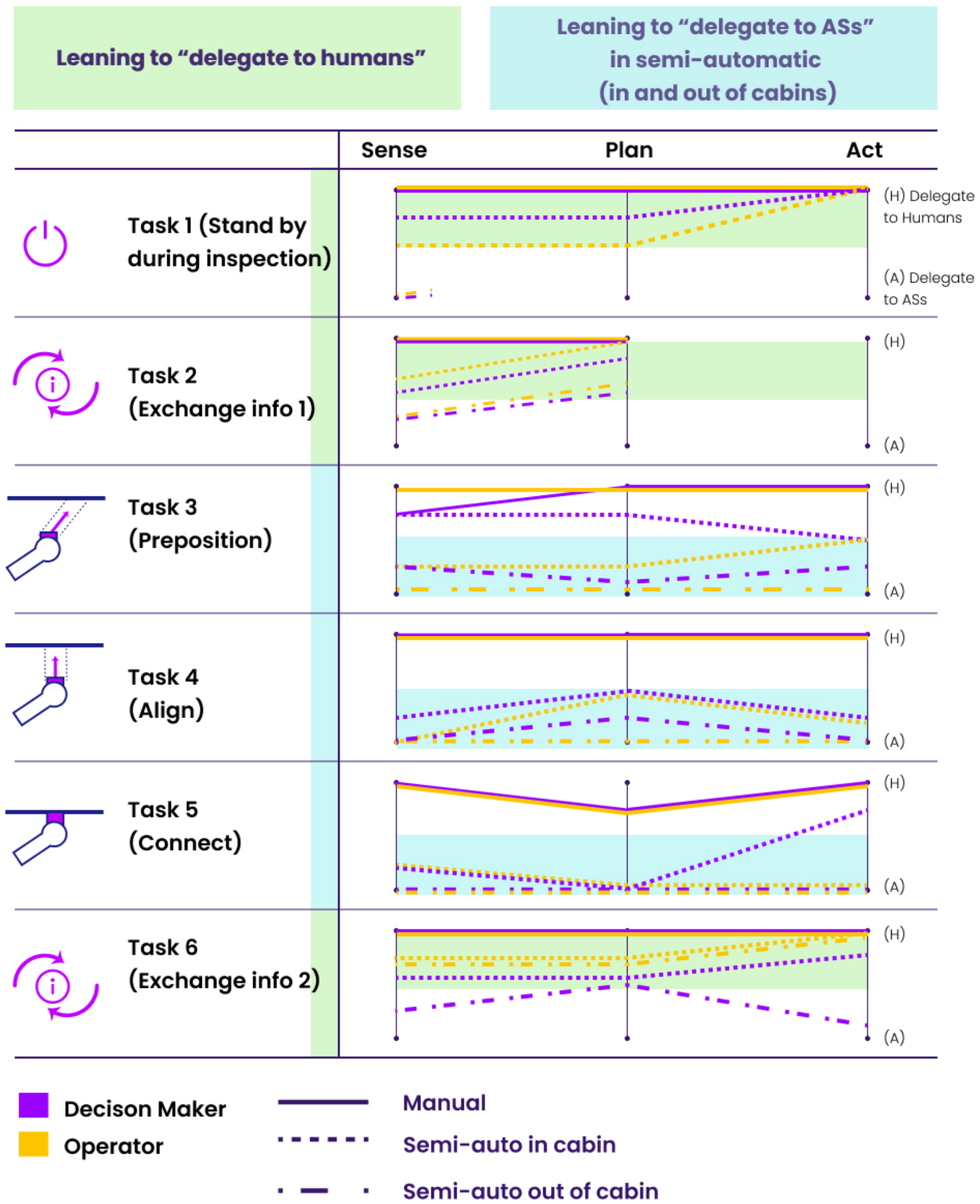
In the contrary, in tasks 3 (i.e., preposition), 4 (i.e, align), and 5 (i.e., connect), the tendency of optimism in automation or overall technology can be found, although the ASs "cannot fix their errors themselves".

> *"Task 3 and 4 can definitely be done automatically" - O_P1*

> *"Self repositioning. Like I said, through the task, three to five is a mostly just, in my opinion, be done." - O_P2*

3) The trend of perception of task delegability regarding LoA

Figure 4.6 illustrates the tendency of task delegability regarding LoA (Beer et al., 2014) based on the interviews. Each cell includes information about to what extent the operators and decision makers prefer to delegate each task to whom, whether Humans or AS, in each sub-tasks regarding Sense, Plan, and Act.



[Figure 4.6 Tendency of task delegability regarding LoA (median: 3 operators, 3 Decision makers)]

In general, both operators and decision-makers recognize the potential for certain tasks 3 (preposition), 4 (align), and 5 (connect) to be performed by Automated Systems (ASs), but there are still preferences for assigning responsibility to humans for tasks 1 (standby while inspection), 2 (exchange info-1), and 6 (exchange info-2).

Task 1, particularly in a PBB setting, is viewed as a task that should primarily be handled by humans, indicating a higher preference for human involvement compared to scenarios outside the PBB. Task 2 reflects the tendency of both operators and decision-makers to prioritize human control, even in semi-automatic situations, with operators placing greater emphasis on this aspect. On the other hand, tasks 3, 4, and 5 lean more towards delegating to ASs, both within and outside the PBB in semi-automatic control scenarios.

When comparing manual, semi-automatic in a PBB, and semi-automatic out of a PBB scenarios, participants tend to delegate more tasks to ASs in the semi-automatic out-of-PBB situation than in the other two scenarios.

Moreover, some differences in perspectives between operators and decision-makers were also found. For task 6 (i.e., exchanging information between operators and flight crews), decision-makers see potential in developing automated solutions for giving signals to cabin crews, while operators perceive this task as critical and prefer to retain human involvement. Additionally, task 5 (i.e., connect) demonstrates that decision-makers are more inclined to delegate the "Act" (i.e., pushing the joystick) aspect of completing the PBB connection within the PBB to humans, compared to outside of it.

4.2.2. Survey

why

The survey was conducted with two objectives: 1) to triangulate the interview findings and 2) to discover correlations between human preferences and task delegation in APBB. Given the limitations in recruiting sufficient interview participants due to operational constraints, the survey allowed for a broader reach and a relatively increased response rate. Moreover, since human preferences significantly influence task delegation, the survey aimed to identify any correlations that may exist.

Participants

Nine respondents, with eight operators and one decision-maker, responded to the survey. The survey was distributed to operators and decision-makers as defined in the In-depth interview. Operators were selected based on their experience with PBB operation, either manual or automatic. Decision-makers account for stakeholders who have knowledge about APBB and influence APPB implementation or development. The survey was also distributed to the In-Depth interview participants after the interview.

[Section 1] For each of the following statements, please indicate the extent to which you agree or disagree for the above task in operating APBB: (five-point Likert scale)		
Motivation	Intrinsic Motivation	"I would feel motivated to perform this task, even without needing to; for example, it is fun, interesting, or meaningful to me."
	Goals	"I am interested in learning how to master this task, not just in completing the task."
	Utility	"I consider this task especially valuable or important; I would feel committed to completing this task because of the value it adds to my life or the lives of others."
Difficulty	Effort	"This task requires a great deal of time or effort to complete."
	Expertise	"It takes significant training or expertise to be qualified for this task."
	(Perceived) Human ability	"I am confident in [my own/a qualified person's] ability to complete this task."
Risk	Accountability	"In the case of mistakes or failure on this task, someone needs to be held accountable."
	Uncertainty	"A complex or unpredictable environment/situation is likely to cause this task to fail."
	Impact	"Failure would result in a substantial negative impact on it adds to my life or the lives of others"
Trust	(Perceived) Machine ability	"I trust the system's ability to complete the task reliably."
	Interpretability	"Understanding the reasons behind the AI agent's actions is important for me to trust the system on this task (e.g., explanations are necessary)."
	Value alignment	"I trust the system's actions to protect my interests and align with my values for this task."
[Secion 2 - repetitive by each 6 tasks] For operators: if you were to do the given (above) task, what level of AI/machine assistance would you prefer? For managers: If you were to ask someone to complete the given (above) task, what level of AI/machine assistance would you prefer?		

[Table 4.3 Survey questionnaires modified from ( )]

Tools and Procedure

The survey utilized an online questionnaire via Qualtrics. It was spread in parallel with the interviews via managers or operators from three handler companies.

Based on the framework for task delegability (Lubars & Tan, 2019), the questionnaire consisted of 18 questions regarding human preference: difficulty, risk, motivation, and trust, related to the delegation of six tasks between humans and ASs as seen in Table 4.3. In difficulty, two aspects (i.e., creativity and social skills) were excluded considering the relevance of the task characteristics. Depending on their PBB experiences, the wording of the questions was adapted. For instance, for operators without APBB experience, questions were formulated using "would." Participants were asked to choose how much they would delegate each task to ASs based on 5-point Likert scale. The detailed questions can be found in Appendix E.

Since there was only one response from decision-makers, the report will primarily focus on the feedback from operators.

Data analysis

First, the Likert scale responses from the section 1 were examined. The median of 8 responses was calculated for each questionnaire of the human preferences, providing a measure of central tendency representing the middle value in the set of responses. The median serves as an indicator of the typical or central response from the survey participants.

To analyze the data from the section 2, a bar chart was created to facilitate a clear comparison of the delegability of each task. This chart visually presents the different levels of delegation for each task, allowing for easy interpretation and analysis of the data.

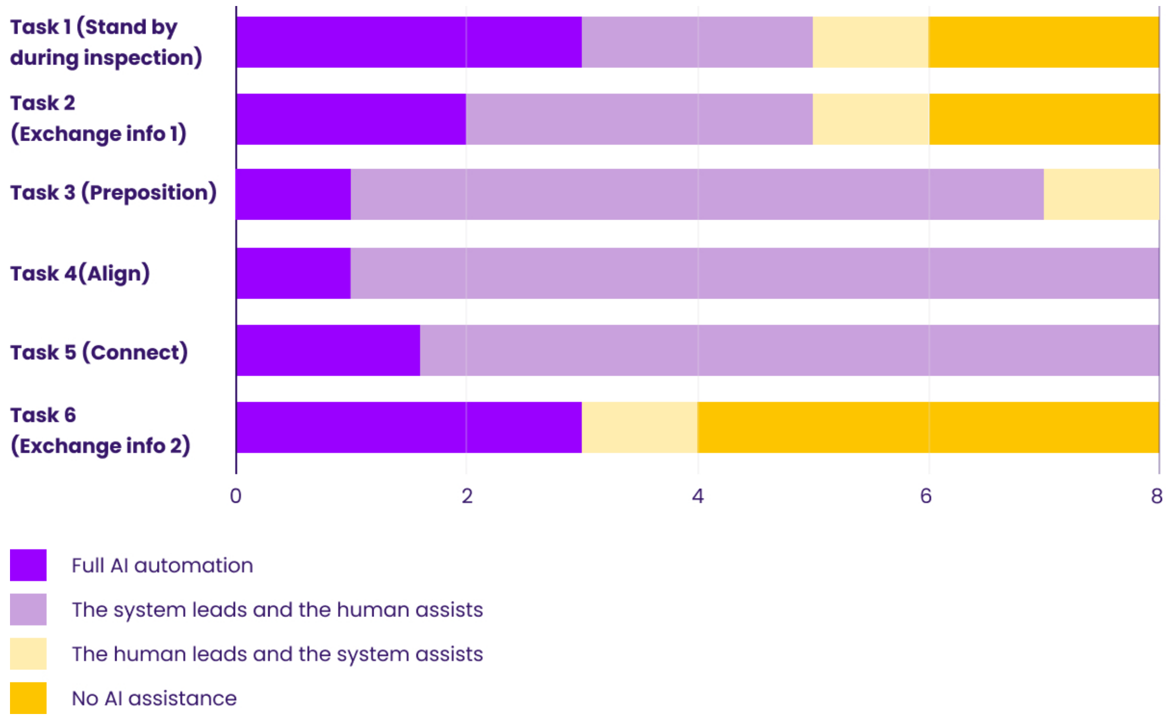
Results

Table 4.4 depicts a consistent trend that aligns with the interview's qualitative data, emphasizing the importance of human involvement in tasks 1, 2, and 6. Task 2, in particular, exhibited the lowest motivation and trust in utilizing ASs among operators. In contrast, tasks 3, 4, and 5 were perceived as requiring higher effort and expertise, indicating greater risks than other tasks.

Furthermore, Figure 4.7 illustrates a similar tendency in willingness of delegating tasks to ASs. In task 3, 4, and 5, which require more precise measurement skills, the majority of participants lean towards delegating these tasks to ASs as assistants. In contrast, task 1, 2, and 6, which involve a task such as "Inspection" and "exchange information", exhibit diverse preferences in the delegation. Although the overall trend towards the option "the system leads and the human assist", there are some responses to "No AI assistance" option, which may lead to further discussion.

	Task1 (Stand by)	Task2 (Exchange Info 1)	Task3 (Preposition)	Task4 (Align)	Task5 (Connect)	Task6 (Exchange info 2)
Difficulty (effort)	1.00	1.00	3.00	3.00	4.00	1.00
Difficulty (expertise)	1.00	1.00	3.50	4.00	4.00	1.00
Difficulty(Human ability)	5.00	5.00	4.00	4.00	4.00	5.00
Risk (accountability)	3.00	4.00	4.50	4.00	4.00	4.00
Risk (uncertainty)	2.00	2.00	3.50	4.00	4.00	2.00
Risk (impact)	2.00	3.00	3.00	3.00	3.00	2.00
Motivation (interest)	2.50	3.00	4.00	4.00	3.50	3.00
Motivation (mastery)	3.00	1.50	3.50	4.00	4.00	3.00
Motivation (Value)	3.00	3.00	3.00	3.00	3.50	3.00
Trust (reliability)	4.00	3.00	3.50	4.00	3.50	3.50
Trust (understandability)	3.00	2.50	3.50	3.00	3.00	3.50
Trust (Value)	3.00	3.00	4.00	4.00	4.00	3.00

[Table 4.4. Median of correlation between Human preferences and tasks in using ASs (Strongly disagree - disagree - neutral - agree - strongly agree, 1-5; N=8)]



[Figure 4.7. Task delegability combining results of all task (N=8)]

4.2.3. Takeaways

12 themes and 4 dimensions from In-depth interviews

1) Challenges of HAC in operation

- Acceptance of Technology & Automation: Participants generally expressed positive attitudes towards technology and automation, recognizing the potential for increased safety and reliability. However, preferences for MPBB and concerns about automation failures were also observed.
- Technical Constraints: Unforeseen technical challenges (e.g., camera failures and limited feedback about errors) were identified. Environmental conditions and uncontrollable factors also pose challenges to the performance of ASs.
- Time-related Challenges: Time efficiency and resolution time were key concerns for decision-makers and operators. The implementation of ASs aimed to improve time efficiency; however, longer resolution times and installation procedures were identified in implementing APBB as a challenge.

2) Working Conditions and Limited Resources

- Labor shortage and unfavorable working conditions were acknowledged as factors affecting job quality. The scarcity of well-trained operators and the varying experience levels of operators influenced task performance and job engagement.

3) Preference for ASs over Humans

- Participants recognized the benefits of ASs in tasks requiring high accuracy, highlighting the potential for reduced human errors, particularly in tasks 3 (i.e., preposition), 4 (i.e., align), and 5 (i.e., connect). However, human oversight and involvement were deemed crucial for critical checks and ensuring overall safety.

4) Preference for Humans over ASs

- Participants emphasized the importance of human involvement in overseeing surroundings and the ASs, particularly while standing by and exchanging information. Even in remote control scenarios, human monitoring was seen as essential.

Tensions of perspectives between operators and managers (SQ 2) from In-depth interviews

The results from the in-depth interviews indicate some differences in perspectives, while the tendency of preference in task delegation is generally consistent between operators and decision-makers. For example, task 6 (i.e., exchanging information between operators and flight crews), decision-makers saw potential in developing automated solutions for giving signals to cabin crews, whereas operators perceived this task as critical and preferred to retain human involvement. Additionally, task 5 (i.e., connect) demonstrates that decision-makers are more inclined to delegate the "Act" (i.e., pushing the joystick) aspect of completing the PBB connection within the PBB to humans compared to outside of it.

Furthermore, concerning time efficiency, decision-makers tend to emphasize maintenance and operational procedures in task delegation, whereas operators prioritize their own performance.

Correlations of human preference and delegation (SQ 1) from the Survey

In exchange information 1 (Task 2), the trend exhibited the lowest motivation and trust in utilizing ASs among operators, in which operator interviewees expressed enjoyment of social interaction. In contrast, the response trend indicates that prepositioning, aligning, and connecting tasks could be delegated to ASs, which were perceived as requiring higher effort, expertise, and risks than other tasks. Figure 4.8 presents he tendency of task delegation.

Pros and cons of controlling in a PBB and out of a PBB

In the comparison among manual, semi-automatic in PBB, and semi-automatic out of PBB scenarios, participants tend to delegate more tasks to ASs in the semi-automatic out-of-PBB situation. Regardless of the operator's location, establishing suitable human-AS interaction is essential.

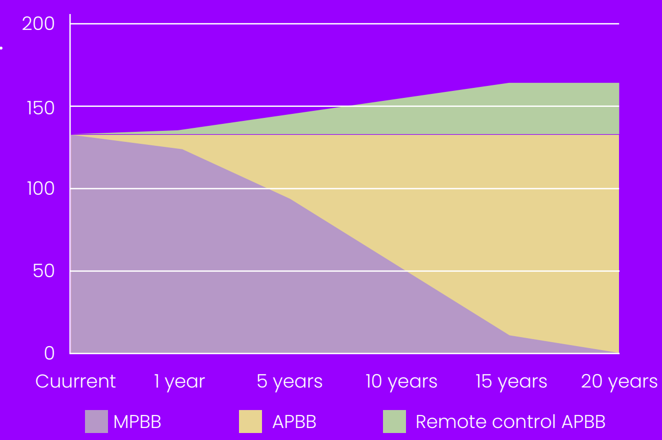
Semi-Automatic Within a PBB: Semi-automatic systems can assist operators within the PBB, boosting efficiency and reducing workload through tasks like distance calculation. While PBB operation allows swift error handling, human supervision bolsters effective human-AS collaboration. Organizational costs for specific in-PBB operators persist, such as employment and training.

Semi-automatic Out of a PBB: Operating from a control room can save operator time, facilitating increased operations. However, seamless communication with flight crews or ground handlers, as in giving a thumbs up sign, poses concerns. Moreover, in the standby (task 1), timing and system synchronization for inspections need attention, requiring departmental cooperation and safety assurance.

Full-automatic Out of a PBB: Operators can have the flexibility to perform tasks beyond PBBs, boosting efficiency. Independent task execution accelerates decision-making and operation. However, interdepartmental information exchange remains a challenge, akin to semi-automatic control. Unsupervised operation can heighten error risk and costs due to limited real-time data. Immediate feedback would be limited, potentially increasing damage repair costs following unnoticed mistakes or collisions.

Time Cost

Exchanging MPBB to APBB requires a long time and agreement to implement gradually. Generally, it may take approximately 1.5 months to remove the old equipment, install the new one, and test it. If each procedure smoothly progresses every month, the expected timeframe when all the PBB is exchanged to APBB will be about 20 years later as seen in Figure 4.8 (Details can be found in Appendix J). This assumption is from the calculation that eight new pieces of equipment can be upgraded annually. However, this view should be more determined based on rigorous planning.

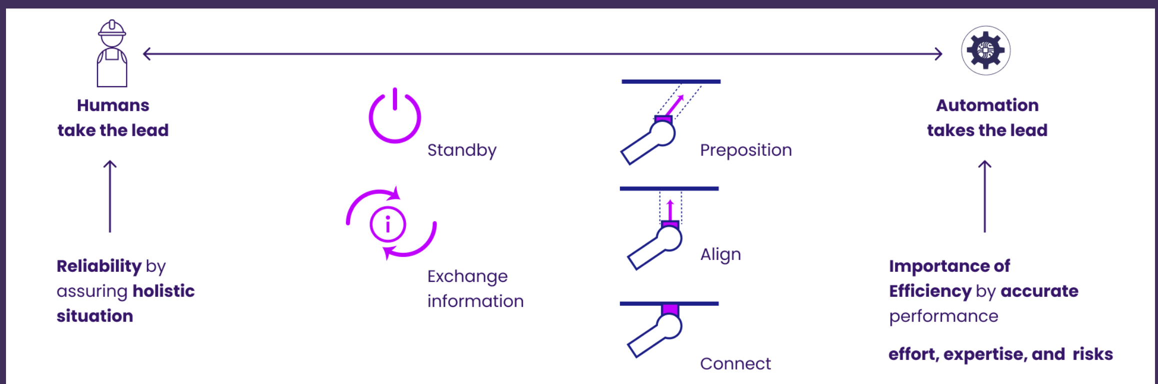


[Figure 4.8. Approximate timeframe in transition of different types of PBB in the AAS]

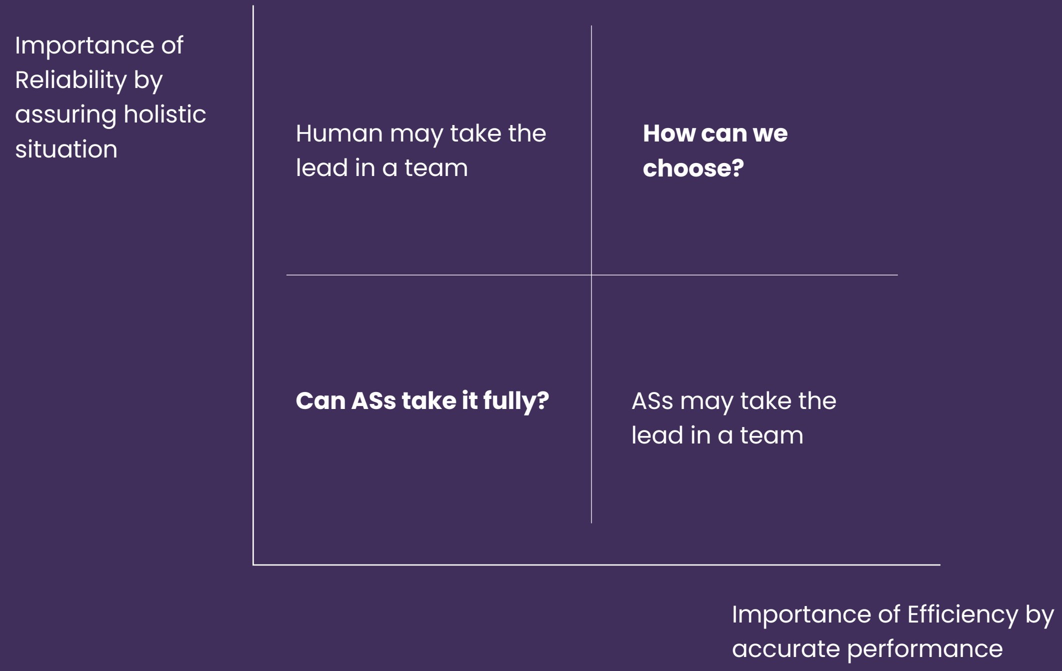
Design Direction

The primary research provides empirical insights about task delegation in different PBB types, which are valuable for organizations to consider to strick the balance of delegation between humans tasks and ASs tasks. Indicating the pros and cons of each type of PBBs, the research findings suggest two controversial values in task delegation: 1) the importance of reliability assuring a holistic situation and 2) the importance of efficiency by accuracy. Figure 4.8 illustrates how ASs may take the lead with human assistance when prioritizing efficiency, while humans tend to lead with ASs' support when emphasizing reliability. They also represent the different perspectives of efficiency and task for the exchange information between decision-makers and operators.

However, when AAO requires both reliability and efficiency as equal importance, as seen in Figure 4.10, it becomes essential to explore how humans can effectively determine the significance of tasks in terms of these two aspects. Diverse factors can also influence task delegation, resulting from different variables (e.g., different types of PBBs, AS errors of ASs, human malfunction, time-related challenges, and adverse weather).



[Figure 4.9. Tendency of task delegation between human and ASs]



[Figure 4.10. Task delegation options based on the importance of two values that may conflict]

To effectively discuss these controversial values and perspectives, simulating possible or probable scenarios in the transition of different types of PBB control is important to design so that organizations can strike the balance of delegation between human tasks and ASs tasks by understanding holistic situations. Therefore, the design direction includes confronting

1) different perspectives of the decision-making process in task delegation,

2) dual different values (i.e., the importance of reliability assuring a holistic situation and the importance of efficiency by accuracy), and

3) diverse scenarios caused by decision-making and different variables.

5. Conceptualization

This chapter is to conceptualize the design based on three design directions from the previous chapter: confronting 1) different perspectives of the decision-making process in task delegation, 2) two different values (i.e., the importance of reliability assuring a holistic situation and the importance of efficiency by accuracy), 3) diverse scenarios caused by decision-making and different variables. In this regard, a decision-making board game as a speculative probe was designed by integrating empirical insights.

5.1. A decision-making board game as a speculative probe: PBB

> *"Not in trying to predict the future but in using design to open up all sorts of possibilities that can be discussed, debated, and used to collectively define a preferable future for a given group of people: from companies, to cities, to societies." _Speculative Design (p. 6)*

The Advantages of Gamification: Exploring Task Delegation and Future Scenarios through a Playful Approach

Following the design direction, a decision-making board game as a speculative probe was designed by integrating empirical insights with several reasons. First, rather than solving problems, future-oriented probes, known as speculative probes, often explore new opportunities by stimulating the present with potential future scenarios, products, or services (Graham, 2007). Scenario-based games can restructure the current situation to provide new insights (Brandt, 2006). Therefore, the game format could show diverse scenarios effectively.

Secondly, games can offer a valuable framework for organizing participation in ASs implementation as effective tools for participatory workshops involving various stakeholders with diverse perspectives. By incorporating fun activities, these games alleviate serious debates, creating an open and engaging space for stakeholders to discuss and bring together key issues freely. In the early days of participatory design, workflow-oriented games were designed to establish a common understanding of the work context (Sjögren, 1991). Today, the objectives remain relevant as these games engage workers in change processes, allowing them to create a shared language, discuss existing realities, explore future visions, and specify requirements (Brandt, 2006). Therefore, the game format will help them to outline the long-term vision and implementation plan for appropriate use in ASs.

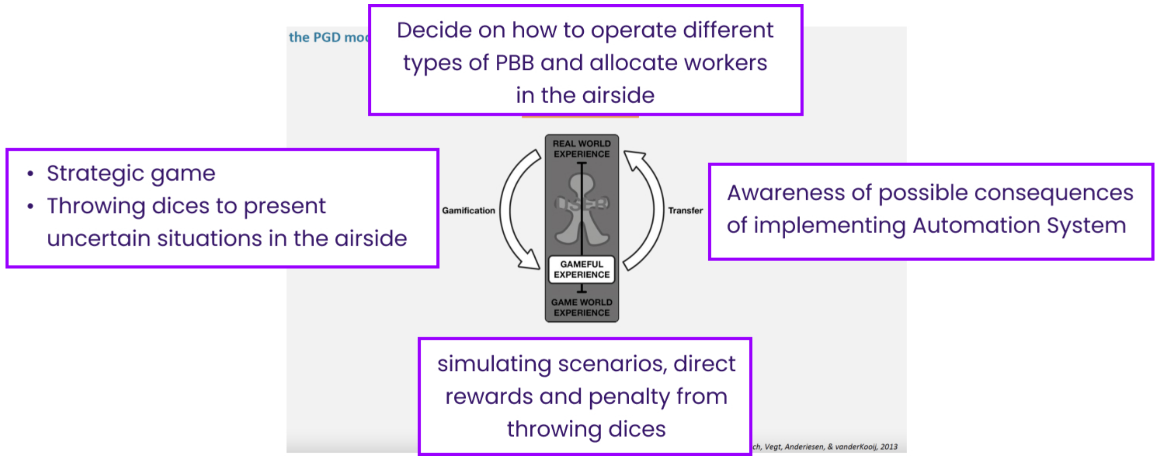
Moreover, using the means of physical games can effectively trigger ways of thinking in implementing and managing automation technology. Through tangible rewards and penalties, the experience of playing the games offers participants the opportunity to integrate values of nature into specific decisions (Lasiewicz-Sych, 2019). Players can play the game to test various scenarios with varied ecosystem outcomes visualized with points won and lost. In addition, while playing a game having physical artifacts, players can retrospect their decision-making process and Internalize the influential factors derived from the primary research. The board game has a key feature that can provoke direct physical contact with other players and prompt feedback after each round (Lasiewicz-Sych, 2019). Tan (2014) also presented the effectiveness of hands-on games that embrace various agencies and derive decision-making from negotiations between stakeholders with existing rule-based iterative processes.

Therefore, the board game could serve as a learning tool (Siriaraya et al., 2018), enabling decision-makers and operators to gain insights into the dynamics of operations and foster a better understanding of each other's roles and perspectives through simulating future scenarios. It is also suggested that games support learning, evolve incrementally, and support open communication, being run on rules, and being collaborative (Tan, 2014).

The objective of the PBB game

The game's objective is for stakeholders to simulate a realistic operational environment and challenge them to make effective decisions while ensuring safety, efficiency, and operator empowerment. The game presents various scenarios as a consequence of their decision on types of PBBs and allocation of workers in the airside. In addition, the game would provide feedback mechanisms to evaluate the consequences of players' decisions. It would encourage players to reflect on their choices, learn from their experiences, and identify areas for improvement in operational management.

Based on the Persuasive Game Design (PGD) model (Visch et al., 2013), the transferred effect through the game was defined (Figure 5.1): awareness of the possible consequences of implementing from manual to full automation. PGD's goal is to develop a user-experienced game environment that will influence user behavior in the real world. Depending on the types of PBB, the number of operators in making decisions could vary. Thus, the decision-makers would be aware of the nature of work in the future and empowering workers, not just replacing them with automation. As an impactful organization, allocating workers can be critical while implementing the ASs.



[Figure 5.1. the Persuasive Game Design (PGD) model (Visch et al., 2013) for our game]

Background of the game context

Airside operation should be under high safety and accuracy secured. Automation can help to achieve it because it is likely that ASs perform better than humans in operation accuracy. However, some situations may not be as efficient as they would be without human beings, even if full automation is possible. Sometimes, different errors or failures occur by automation that humans need to find and repair. In particular, when handlers inspect the environment, non-verbal communication (i.e., thumbs up) between operators is important. Even if the system can be full automated, supervising the system in a real situation leads to easier conditions for quick problem-solving, knowing the context of the errors, compared to the case that someone needs to receive the errors remotely and come over the bridge and figure out the cause of the problem without knowing not much information. It may also increase the delay time, decreasing operation efficiency.

Goal to win

The players delegate tasks to PBB operation operators. The one with the most score (coins + employment index) will win. Although the game is not meant for winning, having the goals can let players have their strategy. Each player has a Personal Board (Figure 5.2a in the next page) to operate two PBBs, starting with 30 coins.

The main flow of the game comprises three phases per round: A) Decision on PBB types and employment, B) Inspection in aircraft arrival, and C) PBB connection.

A) During the Decision phase, players make choices on 1) the types of bridges to use (manual, automatic, automatic+remote), 2) the number of workers to hire, and 3) their placement in the PBB operation process. Appropriate payments are required for each decision. The game consists of 5 rounds.

The bridges mainly come in three types: manual (MPBB), automatic, and automatic combined with remote control. The default setup is the MPBB without additional cost. They can opt to change to automatic PBB, incurring a cost of ten coins each.

Players also have to decide on the number of workers to hire, responsible for operating either the MPBB or APBB. To operate the MPBB, players must locate workers in both A and B areas on the Personal Boards (See figure 5.2a), whereas APBBs do not necessarily require workers in any areas. Hiring one operator costs two coins, and this decision is to be made each round. The employment score increases with each hired employee.

Once the number of workers is determined, players need to place them on their Personal Boards in the airside. In MPBB, workers should be positioned in both A and B areas. In automatic PBB, workers can be either located or unlocated. Area C indicates where a worker operates the APBB from a remote control room, an opportunity exclusively available to players with two APBBs.

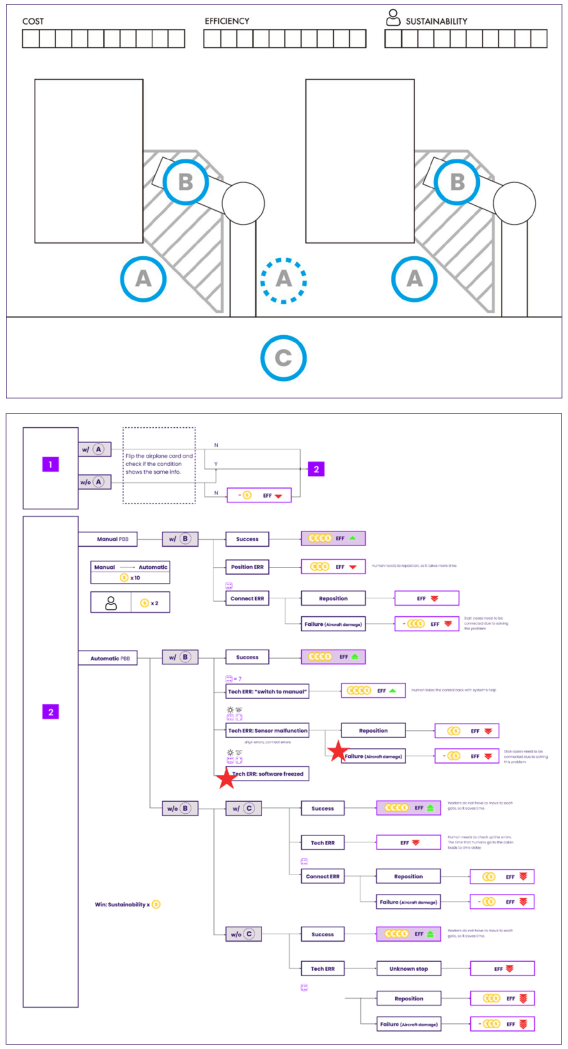
B) In the Inspection of aircraft arrival, players draw two airplane cards from the deck and put them on the ramps in their personal Boards (Figure 5.2). The players flip the airplane cards if they do not put the workers in the A area. If the card picture is the same, it will go to the next step. However, if the card picture describes different facts yet with no A in their PBB, the player should decrease the efficiency scale and pay the corresponding coins. This infers that the aircraft conditions could differ from those reported before arrival. In this case, the automatic sensors may miss important information, such as door damage, debris, oil leakage, or some obstacles, leading to an operation delay. These factors were derived from the In-depth interview.

C) In the PBB connection, the first player throws three dice and follows the steps in the flow board (Figure 5.2b) by calculating their sum. The outcome determines the scenario, deciding whether the player successfully connects the PBB or encounters errors or failures. Based on the consequence, compensations or costs occur, including adjustments to the efficiency level.

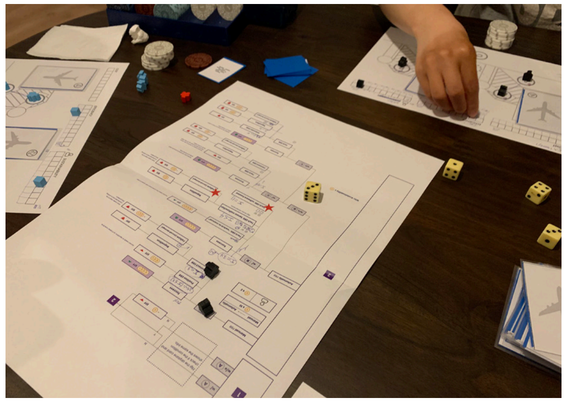
5.2. Low-fidelity prototyping and testing

5.2.1. The first prototype

To examine issues related to the gameplay, ‘Quick and dirty’ tests were carried out with two iterations. In the first test with the initial design, three players including the main researcher played the game following the rule, considering balance, level of challenge, difficulty, understandability, etc. After the quick test, the second low-fidelity prototype (Figure 5.5) was developed based on the implications of the first game testing.



[Figure 5.2 The initial Low-fidelity prototype: Top(a) - Personal Board, Bottom(b) - Flow Board]



[Figure 5.3 Testing the first low-fidelity prototype]

Findings

Rules

Improving the clarity of the game's strategy is necessary. It currently lacks clear guidelines on decision-making to make more money and efficiency as well as hiring workers.

Confusion regarding the allocation of workers in APBB was discovered. A clearer explanation was needed as humans can be allocated regardless of the PBB type.

To experience diverse scenarios in one game, assigning a role to a player could be another way.

After upgrading the PBB into APBB, the game should address the potential scenario of firing workers. Extra costs or penalties can be considered that players should pay for terminating workers.

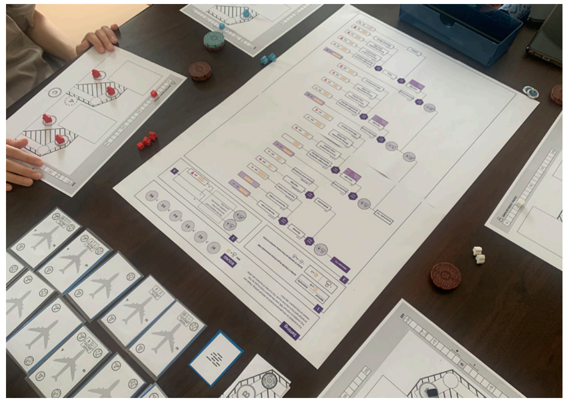
Design

The components to indicate “upgrading PBB into Automatic” needs to be designed since it does not show the difference when players upgrade the bridge into APBB.

The game mechanism should ensure that the number of dice results in a probability that realistically balances the success and failure rates, thus mirroring real-world scenarios.

Task 6 (give signs to Cabin crew) was also important but was overlooked in this game. Including this would be more valuable, but the game would become more complex.

5.2.2. The second prototype



[Figure 5.4 Testing the second low-fidelity prototype]

Development

The Flow Board (Figure 5.5b) outlines players' chronological steps during the game.

The icon representing the location of workers on the flow board was redesigned to distinguish between different PBB types and types of workers.

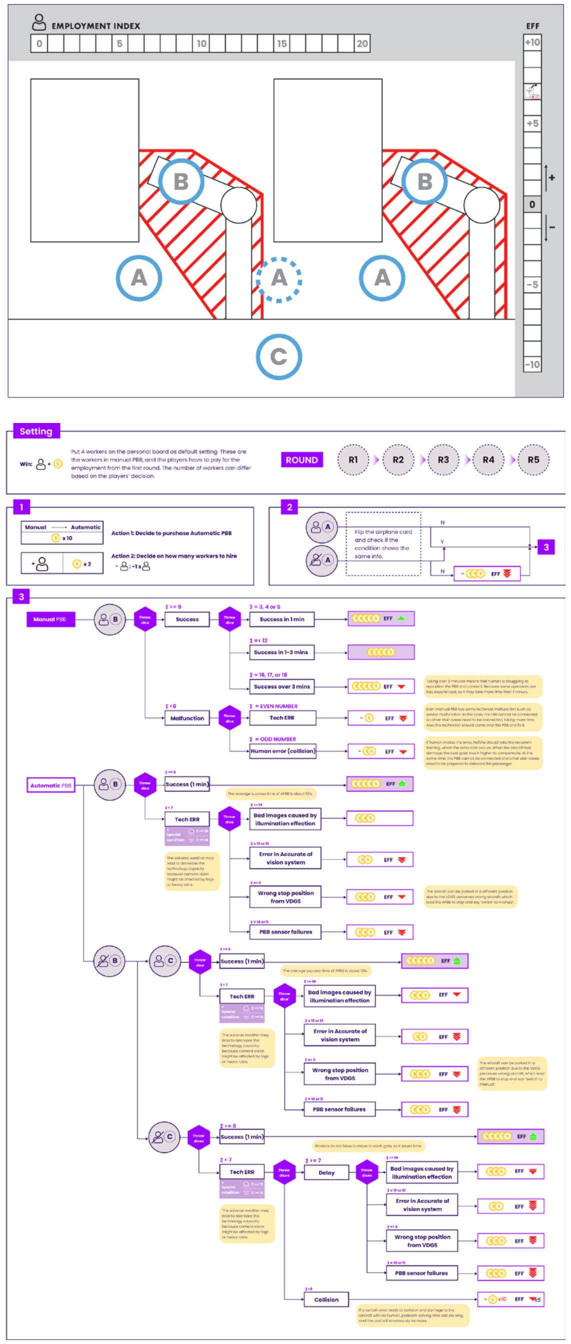
During gameplay, players can choose whether each player starts with different types of PBB or default (i.e., manual). However, it needs to be developed further.

Regarding firing workers, players will incur penalties, decreasing one employment index from their Personal Board.

Additional components were incorporated into the game, such as indicators for different rounds and the option to upgrade APBB.

To depict real-world conditions as accurately as possible, in-game possibilities were determined by taking into account figures derived from interviews and internal tests conducted between 2018 and 2020. Some possibilities have been exaggerated to make the game run effectively. For example, the failure rates between APBB and passive PBB are 0.7% and 1.2%, respectively. However, both are very low percentages for designing the dice-throwing game. In the failure rate, the ratio of APBB to passive PBB is the same as in reality, but the probability increases by 15% and 25%, respectively.

Despite these improvements, the game still has room for further enhancement.



[Figure 5.5 The second Low-fidelity prototype: Top(a) - Personal Board, Bottom(b) - Flow Board]

The second playtesting was conducted to examine the game's new design. Four players with design backgrounds played one time. It took around 1 hour.

Findings from the 2nd test

- To enhance clarity in the game, detailed explanations of the roles of operators in areas A, B, and C should be provided. Players need a clear understanding of the tasks and responsibilities associated with each area to make informed decisions during gameplay.
- For the aircraft condition cards, using icons with only one side to differentiate the conditions would make it easier for players to identify and react to the card's information quickly.
- Giving a dedicated reflection time would be valuable for players to discuss their decisions, insights, and thoughts about automation and hiring workers. It's not about a winning game but more about a reflecting game. The progress they made decisions should be visible. For example, tracing each round's decisions can be important for players to look back at each player's choices and outcomes in previous rounds.
- Regarding societal issues, additional elements could be introduced to represent workers' happiness or social connections between them. These aspects can have implications for the overall performance and well-being of the workforce, impacting the players' decision-making process.
- A purpose card with specific goals can help players to engage in various situations.

5.2.3. Takeaways

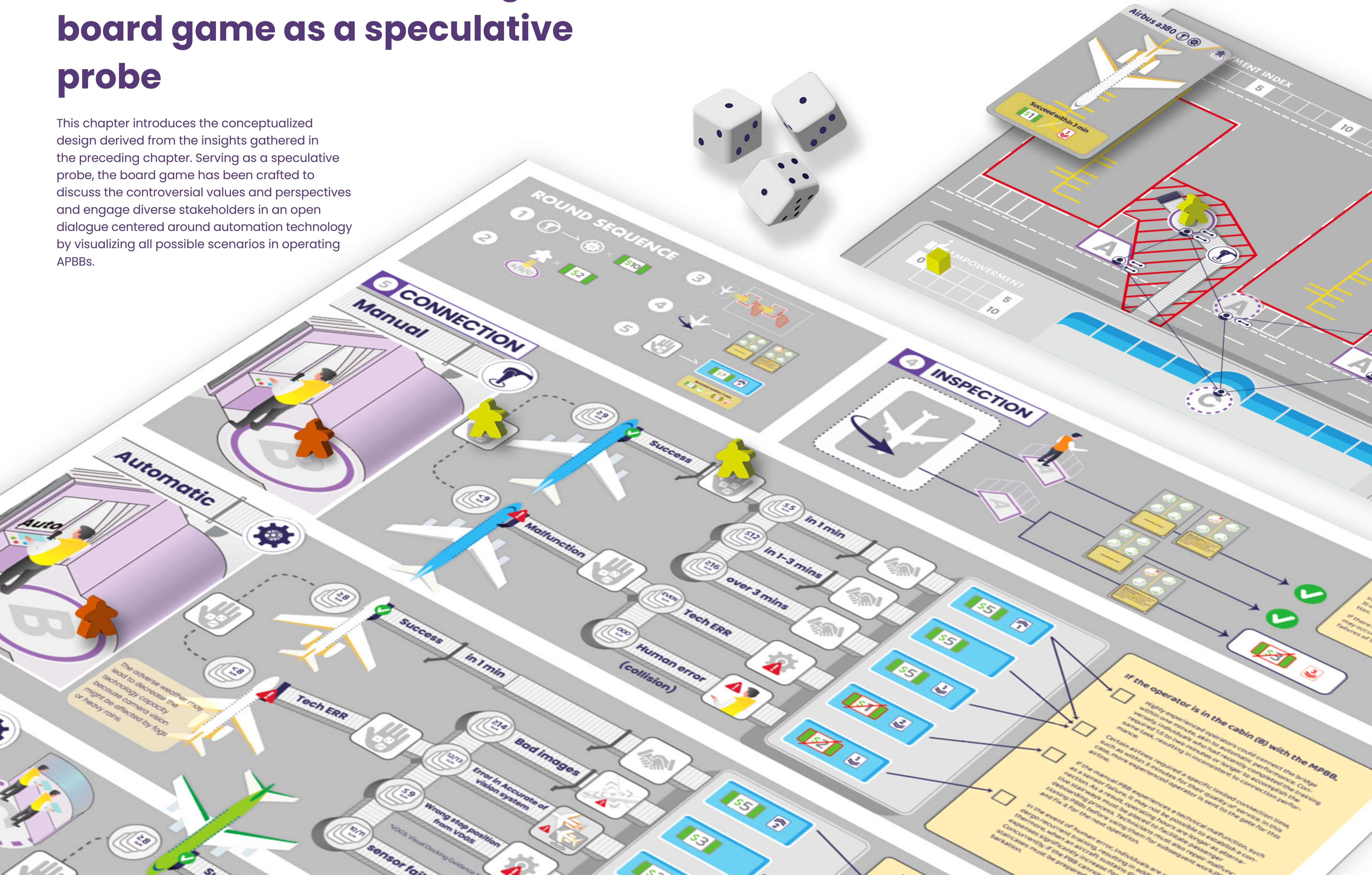
The board game as a speculative probe was created with iterative processes in order for organizations to experience diverse future scenarios, to retrospect their decision-making process of using automation technology, and to facilitate different point of views regarding the technology.

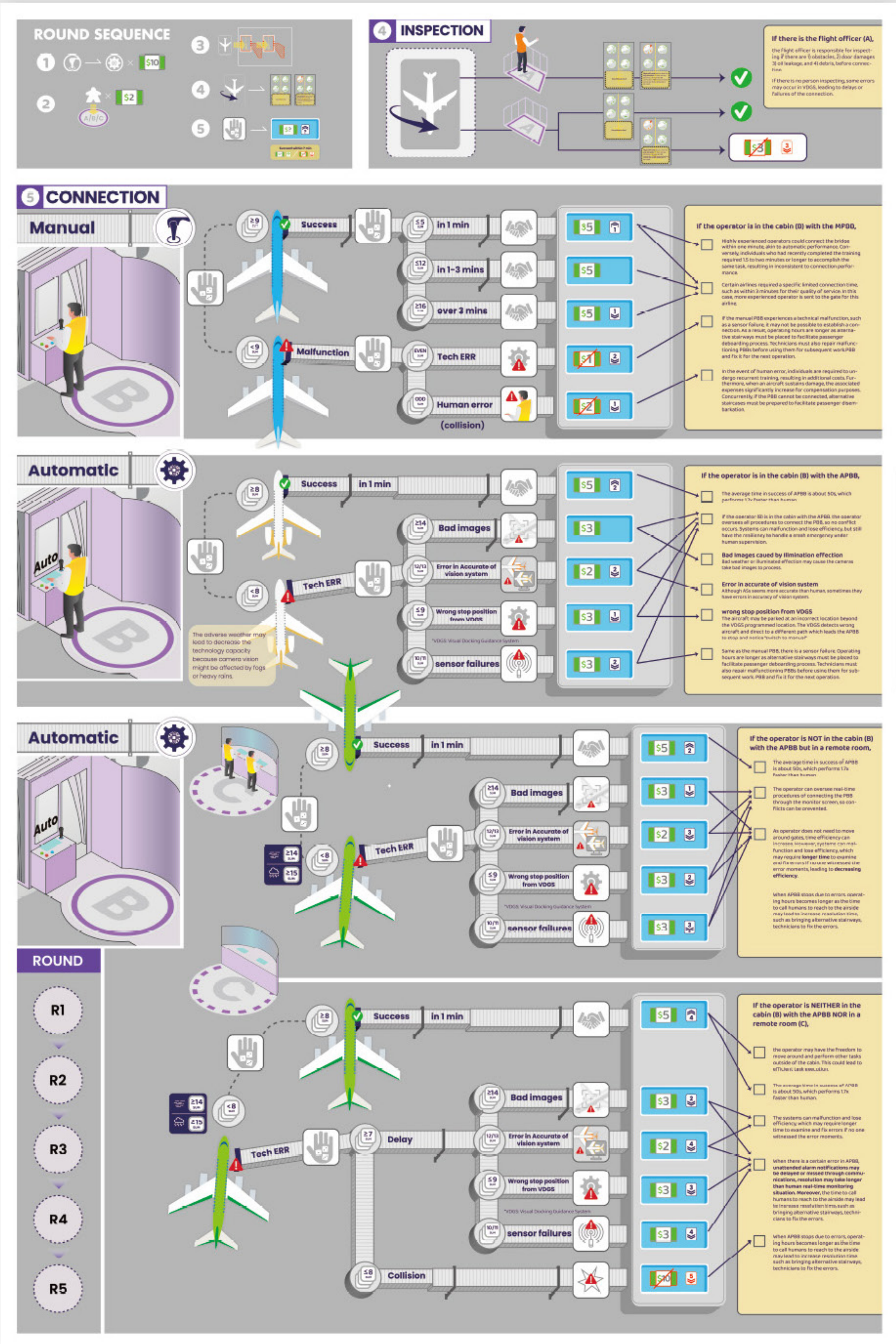
In order to test the gameplay and transferred effect of the probe, two iterations with low-fidelity prototypes were conducted.

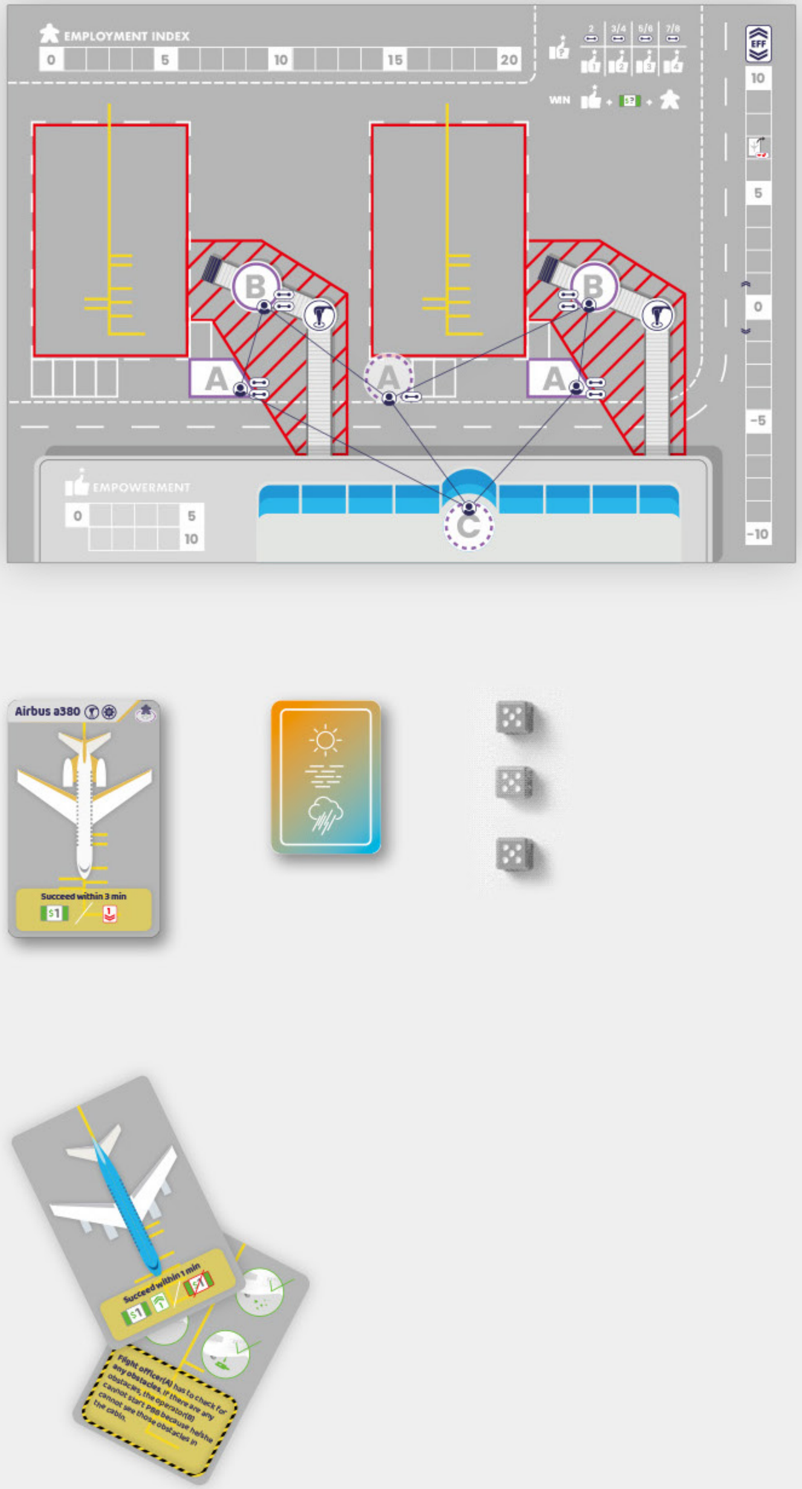
With these findings from the "Quick and Dirty" tests, the final version of the game was developed in the next chapter.

6. PBB: A decision-making board game as a speculative probe

This chapter introduces the conceptualized design derived from the insights gathered in the preceding chapter. Serving as a speculative probe, the board game has been crafted to discuss the controversial values and perspectives and engage diverse stakeholders in an open dialogue centered around automation technology by visualizing all possible scenarios in operating APBBs.







[Figure 6.1. Overview of the final design: left(a)-flow board, top right(b) - personal board, flight cards(c), weather cards(d), and 3 dice]

6.1. Design Description

6.1.1. 21 scenarios on the flow board

The Flow Board (Figure 6.1a) encompasses 21 scenarios (Table 6.1) that players can encounter based on their decisions. The progression of these scenarios primarily relies on dice rolls, with the possibilities derived from the research. However, the player's choices determine the starting point of the flow. Further details on the design mechanism, including the calculation of possibilities, can be found in Appendix F.

Types of PBB	Presence of operators	Flow of scenarios			Scenario Number
Manual PBB	with B	Success	Success in 1 min		1
			Success between 1-3 min		2
			Success longer than 3 min		3
		Error	human error (collision)		4
			Sensor failures		5
Automatic PBB	with B	Success in 1 min			6
		Technical errors (switch to manual / stop)	Bad images caused by illumination effection		7
			Accurate of vision system		8
			Wrong stop position / wrong aircraft type from VDGS		9
			PBB sensor failures		10
	without B + with C	Success in 1 min			11
		Technical errors (switch to manual / stop)	Bad images caused by illumination effection		12
			Accurate of vision system		13
			Wrong stop position / wrong aircraft type from VDGS		14
			PBB sensor failures		15
	without B & C	Success in 1 min			16
		Tech errors (switch to manual / stop / crash)	Delay	Bad images caused by illumination effection	17
				Accurate of vision system	18
				Wrong stop position / wrong aircraft type from VDGS	19
				PBB sensor failures	20
			crash and damage to aircraft		21

[Table 6.1. Scenarios on the Flow Board]

6.1.2. Round sequence

The round sequence consists of seven steps that each player needs to act. To facilitate comprehension during gameplay, Figure 6.2 has been provided to each participant.

1) Flip the weather card

2) Decide on the types of PBB

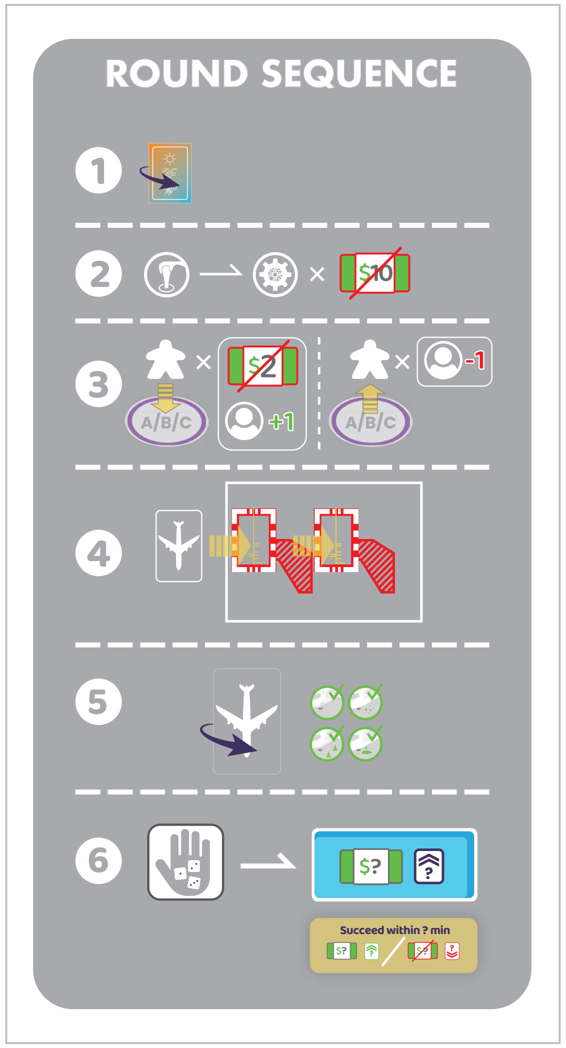
3) Hire operators and allocate them to a location for operations

4) Aircraft landing

5) Inspect the aircraft landed

6) Connect PBBs to the aircraft

7) Reflect the choices with the Reflection sheet



[Figure 6.2. Round sequence]

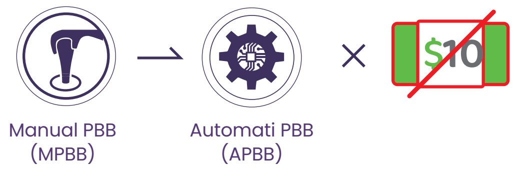
1) Flip the weather card

In each round, the gameplay will be affected by specific weather conditions determined by the weather card (Figure 6.3). Adverse weather can potentially influence the functionality of ASs. For example, rain or foggy weather may undermine the capabilities of ASs compared to a sunny day.

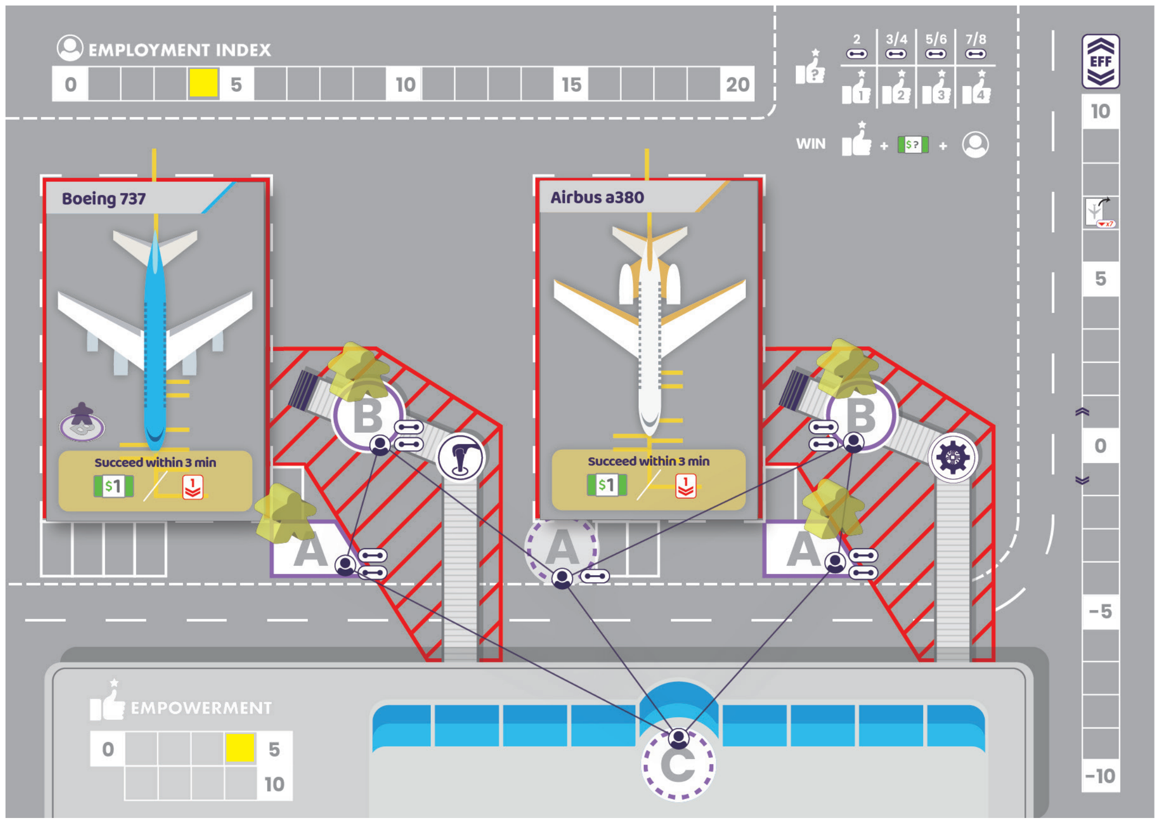
[Figure 6.3. Different weathers determined the weather card]

2) Decide on the types of PBBs

Players can operate two MPBBs each round on their Personal Board (Figure 6.5). When players upgrade the MPBB to the APBB, players should pay for APBB with ten coins (Figure 6.4). Figure 6.5 shows examples that a player decides to upgrade one APBB.



[Figure 6.4. Ten coins needed for upgrading to an APBB]

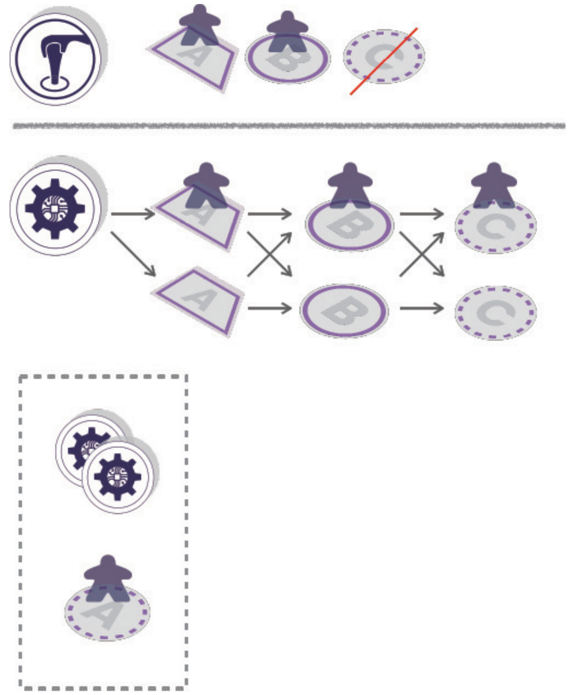


[Figure 6.5. Personal Board for operating two PBBs (e.g., the left one refers to MPBB, the right one is APBB) with four operators located in area A and B]

3) Hire operators and allocate them to a location for operations

Players can allocate human operators to areas A, B, and C by hiring them for two coins each. In the MPBB operation, human operators are required in areas A and B. However, in the case of the Automatic PBB (APBB) systems, players do not need to hire operators for areas A, B, and C. Area C serves as the location where operators can control the PBB remotely. According to the number of hired workers, the score of the employment index and empowerment index are determined.

As for the efficiency levels are subject to adjustments based on the success, errors, or collisions that occur during the connecting of PBBs. Once the efficiency level reaches 7 points, players gain an additional chance to operate one more flight connection before the next round commences, after which the efficiency level resets back to 0.

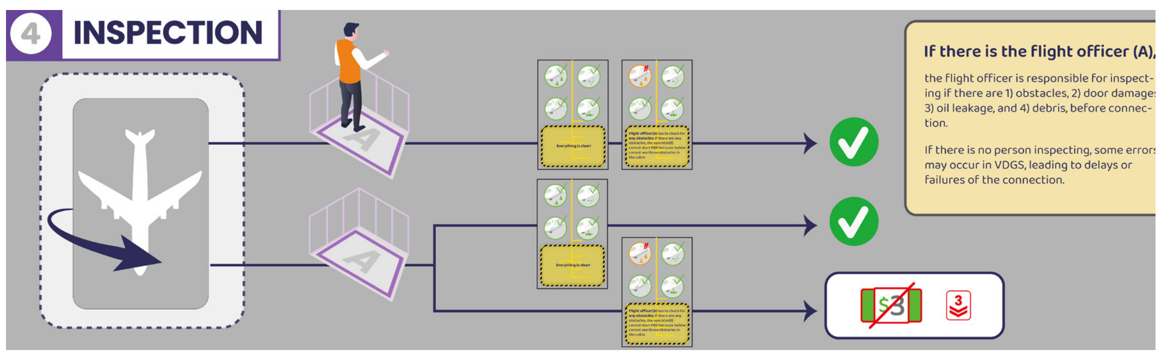

[Figure 6.6. Configuration of workers regarding the types of PBBs]

4) Aircraft landing

Before connecting the PBBs, players must inspect the aircraft landing. They select two flight cards from the opened cards on the card deck and place them on their Personal Boards (Figure 6.5). The first player will be the one with the highest Employment Index.

5) Inspect the aircraft landed

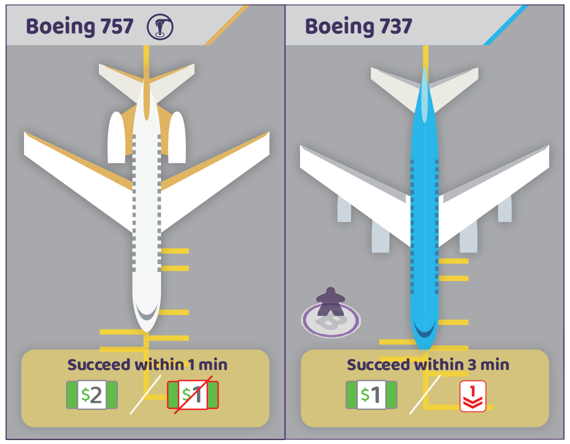
After placing the flight cards on their Personal Boards, the players must flip the cards and check the back side for any defects on the aircraft or its surroundings (Figure 6.7).



[Figure 6.7. Inspection flow]

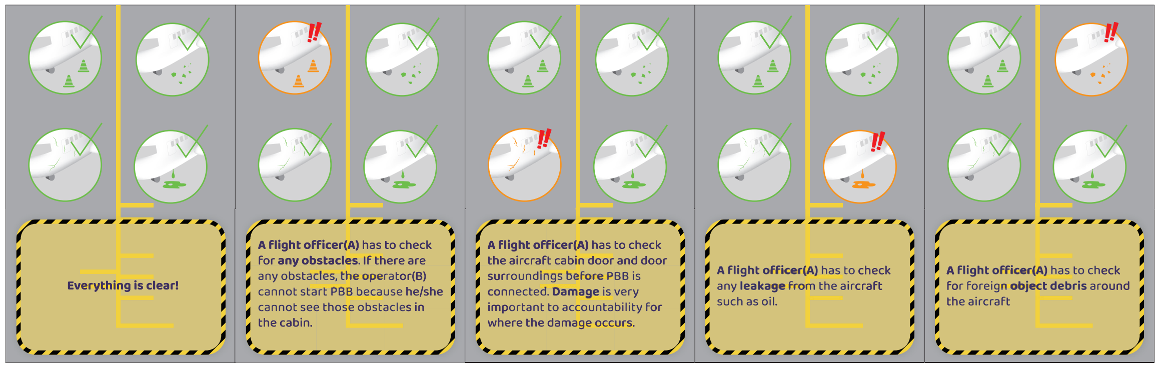
On the front side of the flight cards (Figure 6.8), there is information about the aircraft with special conditions.

- Certain aircraft can only be connected with MPBB when the card includes the MPBB icon.
- Some have specific conditions in a yellow box to achieve and additional compensations if the operation is successful. However, if the operation fails, the player has to pay the cost indicated on the card.
- Even though some aircraft can be connected with APBB, certain airlines require operators to be in the PBB (i.e., area B) during the connection.



[Figure 6.8. The front side of the flight cards]

On the back side (Figure 6.9), various situations that the flight officer (A) needs to inspect are depicted. The situations can be "everything is clear," while during the game, four issues may be discovered: 1) obstacles, 2) door damage before connection, 3) oil leakage, and 4) debris. If the player does not have an operator located in area A and flips a card with any of these issues, the player needs to pay three coins and decrease one efficiency level (See figure 6.7). This indicates that errors may lead to delays or failures in the connection. However, when an operator is located in area A, they can handle these issues in advance, assuring the problems in advance for a smooth operation.

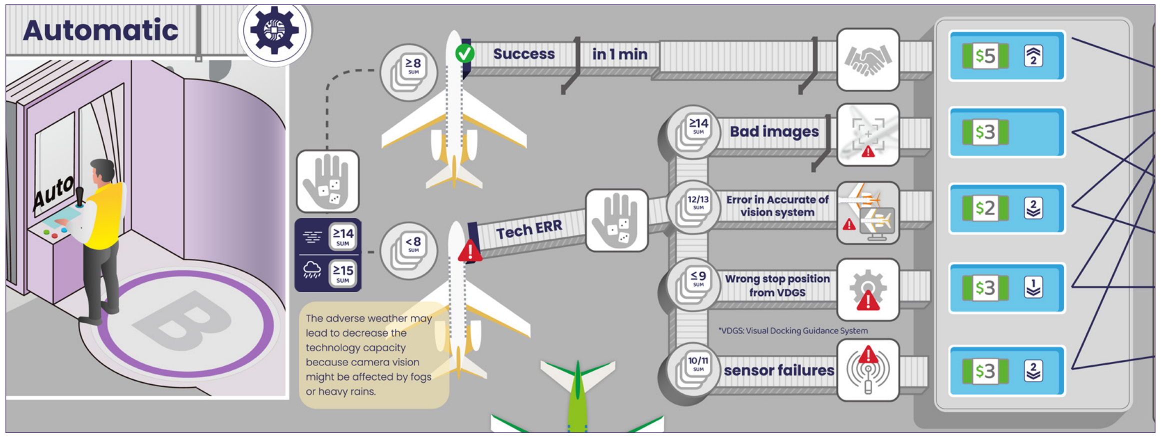


[Figure 6.9. The backside of the flight cards]

6) Connect PBBs

Players will have two turns because they operate 2 PBBs in each round by rolling the three dice. The outcomes may lead to different scenarios. By calculating the sum of the three dice, a particular scenario will be determined, which decides whether the player can successfully complete the docking or encounter errors or failures. Depending on the scenario, players will receive rewards or incur costs, including changes in efficiency. The success or failure of the mission will also result in players receiving rewards or paying penalties accordingly.

Taking an example of managing an APBB with a worker in area B (Figure 6.10). In the event that the total displayed on the dice is 9, the scenario leads to a successful outcome. Conversely, if the cumulative number is less than 8, it results in technical errors, necessitating an additional dice roll. Subsequently, the specific error type encountered among the four possibilities is determined based on the number rolled.



[Figure 6.10. Five different scenarios of operating APBB with an operator in area B depending on cumulative number of dice]

7) Reflect the decision with the Reflection sheet

To reflect on the decisions on each round and to have a discussion after the game, the players have to check how they made decisions on which types of PBB, how many workers were hired, and how much efficiency and gold were given each round on the Reflection card (Figure 6.11). During or after five rounds, the participants can write some memos for remarks.

	Flight officer (A)	PBB operator in a cabin (B)	APBB operater in remote room (C)	Bridge type	Efficiency	Earned Gold	Reflection
Round 1	☐	☐	☐	B1			Please share your thoughts about your decision-making progress.
	☐	☐	☐	B2			
Round 2	☐	☐	☐	B1			
	☐	☐	☐	B2			
Round 3	☐	☐	☐	B1			
	☐	☐	☐	B2			
Round 4	☐	☐	☐	B1			
	☐	☐	☐	B2			
Round 5	☐	☐	☐	B1			
	☐	☐	☐	B2			

[Figure 6.10. The reflection card]

+ Explanation cards (Figure 6.11.)

Following the transition to specific scenarios, players have the opportunity to explore the underlying rationales behind the rewards and costs associated with their decisions through corresponding explanation cards. These cards provide contextual background information derived from actual PBB operations. This supplementary layer of information enables players to gain a deeper understanding of the implications of their choices by delving into the real-world factors influencing the outcomes.

If the operator is in the cabin (B) with the MPBB, Highly experienced operators could connect the bridge within one minute, akin to automatic performance. Conversely, individuals who had recently completed the training required 1.5 to two minutes or longer to accomplish the same task, resulting in inconsistent to connection performance.	**If the operator is in the cabin (B) with the MPBB,** Certain airlines required a specific limited connection time, such as within 3 minutes for their quality of service. In this case, more experienced operator is sent to the gate for this airline.	**If the operator is in the cabin (B) with the MPBB,** If the manual PBB experiences a technical malfunction, such as a sensor failure, it may not be possible to establish a connection. As a result, operating hours are longer as alternative stairways must be placed to facilitate passenger deboarding process. Technicians must also repair malfunctioning PBBs before using them for subsequent work.PBB and fix it for the next operation.	**If the operator is in the cabin (B) with the MPBB,** In the event of human error, individuals are required to undergo recurrent training, resulting in additional costs. Furthermore, when an aircraft sustains damage, the associated expenses significantly increase for compensation purposes. Concurrently, if the PBB cannot be connected, alternative staircases must be prepared to facilitate passenger disembarkation.	**If the operator is in the cabin (B) with the APBB,** wrong stop position from VDGS The aircraft may be parked at an incorrect location beyond the VDGS programmed location. The VDGS detects wrong aircraft and direct to a different path which leads the APBB to stop and notice "switch to manual"
If the operator is in the cabin (B) with the APBB, The average time in success of APBB is about 50s, which performs 1.7x faster than human.	**If the operator is in the cabin (B) with the APBB,** If the operator (B) is in the cabin with the APBB, the operator oversees all procedures to connect the PBB, so no conflict occurs. Systems can malfunction and lose efficiency, but still have the resiliency to handle a crash emergency under human supervision.	**If the operator is in the cabin (B) with the APBB,** Bad Images caued by Illumination effect Bad weather or illuminated effection may cause the cameras take bad images to process.	**If the operator is in the cabin (B) with the APBB,** Error in accurate of vision system Although ASs seems more accurate than human, sometimes they have errors in accuracy of vision system.	**If the operator is in the cabin (B) with the APBB,** Same as the manual PBB, there is a sensor failure. Operating hours are longer as alternative stairways must be placed to facilitate passenger deboarding process. Technicians must also repair malfunctioning PBBs before using them for subsequent work. PBB and fix it for the next operation.
If the operator is NOT in the cabin (B) with the APBB but in a remote room, The average time in success of APBB is about 50s, which performs 1.7x faster than human.	**If the operator is NOT in the cabin (B) with the APBB but in a remote room,** The operator can oversee real-time procedures of connecting the PBB through the monitor screen, so conflicts can be prevented.	**If the operator is NOT in the cabin (B) with the APBB but in a remote room,** As operator does not need to move around gates, time efficiency can increase. However, systems can malfunction and lose efficiency, which may require longer time to examine and fix errors if no one witnessed the error moments, leading to decreasing efficiency.	**If the operator is in the cabin (B) with the APBB,** When APBB stops due to errors, operating hours becomes longer as the time to call humans to reach to the airside may lead to increase resolution time, such as bringing alternative stairways, technicians to fix the errors.	
If the operator is NEITHER in the cabin (B) with the APBB NOR in a remote room (C), the operator may have the freedom to move around and perform other tasks outside of the cabin. This could lead to efficient task execution.	**If the operator is NEITHER in the cabin (B) with the APBB NOR in a remote room (C),** The average time in success of APBB is about 50s, which performs 1.7x faster than human.	**If the operator is NEITHER in the cabin (B) with the APBB NOR in a remote room (C),** The systems can malfunction and lose efficiency, which may require longer time to examine and fix errors if no one witnessed the error moments.	**If the operator is NEITHER in the cabin (B) with the APBB NOR in a remote room (C),** When there is a certain error in APBB, unattended alarm notifications may be delayed or missed through communications, resolution may take longer than human real-time monitoring situation. Moreover, the time to call humans to reach to the airside may lead to increase resolution time, such as bringing alternative stairways, technicians to fix the errors.	**If the operator is NEITHER in the cabin (B) with the APBB NOR in a remote room (C),** When APBB stops due to errors, operating hours becomes longer as the time to call humans to reach to the airside may lead to increase resolution time, such as bringing alternative stairways, technicians to fix the errors.

[Figure 6.11. Explanation cards]

7. Evaluation

This chapter describes the evaluation process of the design. The design goal is for organizations to strike a balance between the decision-making authority retained by humans and that can be transferred to ASs.

7.1. Evaluation

Why

To examine how the design goal is achieved, three evaluation sessions were conducted with the following questions:

- Can the design lead participants to confront different perspectives of the decision-making process in task delegation
- Can the design provoke participants to confront two different values between the importance of reliability assuring a holistic situation and the importance of efficiency by accuracy?
- Can the design help organizations envision possible/probable scenarios of how HAC may be changed with different variables?
- How can the design be practical for decision-makers to open up discussions and make decisions in task delegation?

7.1.1. Method

Pilot Test

A pilot test involving two participants was conducted to refine the real evaluation session, providing valuable insights for improvement. These participants were recruited through direct contact with the main researcher at IH.

One key recommendation was to assign roles at the game's start instead of allowing free choice, ensuring participants encountered diverse scenarios. In the pilot test, the participants were free to choose the types of PBBs, resulting in less dynamic diversity. While freedom of choice would be ideal with sufficient playtime, the limited evaluation session only allowed for 2-3 rounds, making it challenging to observe significant differences. Moreover, having more than two players would lead to increased interactions and a broader range of scenarios to observe and analyze.

Participants

Overall, three evaluation sessions were conducted, each involving three participants, resulting in a total of nine participants as seen in Table 7.1. The median age of participants is 39.5, and the median of work experience is 13. They are either in decision-making positions or APBB operators. The operators were recruited through a contact provided by one operator, and this operator assisted in the random selection of participants. Decision-makers targeted were those who had engaged in automation projects, and relevant individuals within RSG in these capacities were contacted directly. Nevertheless, owing to the holiday season, decision-makers associated with APBBs could not participate in the evaluation sessions.

Each session consisted of a different group. In Session 1, decision-makers participated, while Session 2 exclusively included operators to validate the representativeness of the PBB operational context. After having two sessions, the third session with a mixed group of decision-makers and operators was organized to evaluate if the probe design could facilitate diverse perspectives from various stakeholder groups.

Group	No.	Description	Work Experience (yrs)	Age	Gender
Session 1 (Decision-makers)	DM1	Stakeholder in relation to automation projects	6-10	25-34	Male
	DM2	Stakeholder in relation to automation projects	11-15	35-44	Male
	DM3	Stakeholder in relation to automation projects	6-10	25-34	Female
Session 2 (Operators)	O1	APBB Operator	20-	45-54	Male
	O2	APBB Operator	16-20	45-54	Male
	O3	APBB Operator	20-	45-54	Male
Session 3 (Mixed)	O4	APBB Operator	16-20	45-54	Female
	DM4	Stakeholder in relation to automation projects	1-5	19-24	Female
	DM5	Stakeholder in relation to automation projects	1-5	19-24	Female

[Table 7.1 Demographics of participants]

Tools and procedure

Tools

- Informed Consent (Appendix I)
- Physical board game components
- A tutorial slide for the introduction of the game (Appendix G)
- Reflection sheet - To reflect on players' decisions on each round and to discuss the game's effect

Protocols (est. 1hr 20min)

- Introduce the research purpose with a consent form (3 mins)
- Explain the game rule and goals with a tutorial video (5 mins)
- 2-3 rounds were played depending on how participants understand the game and play it. During the play, the player wrote down their decisions after each round for further discussion. (50 mins)

After the play, there was a debrief for 20 minutes with semi-structured questions:

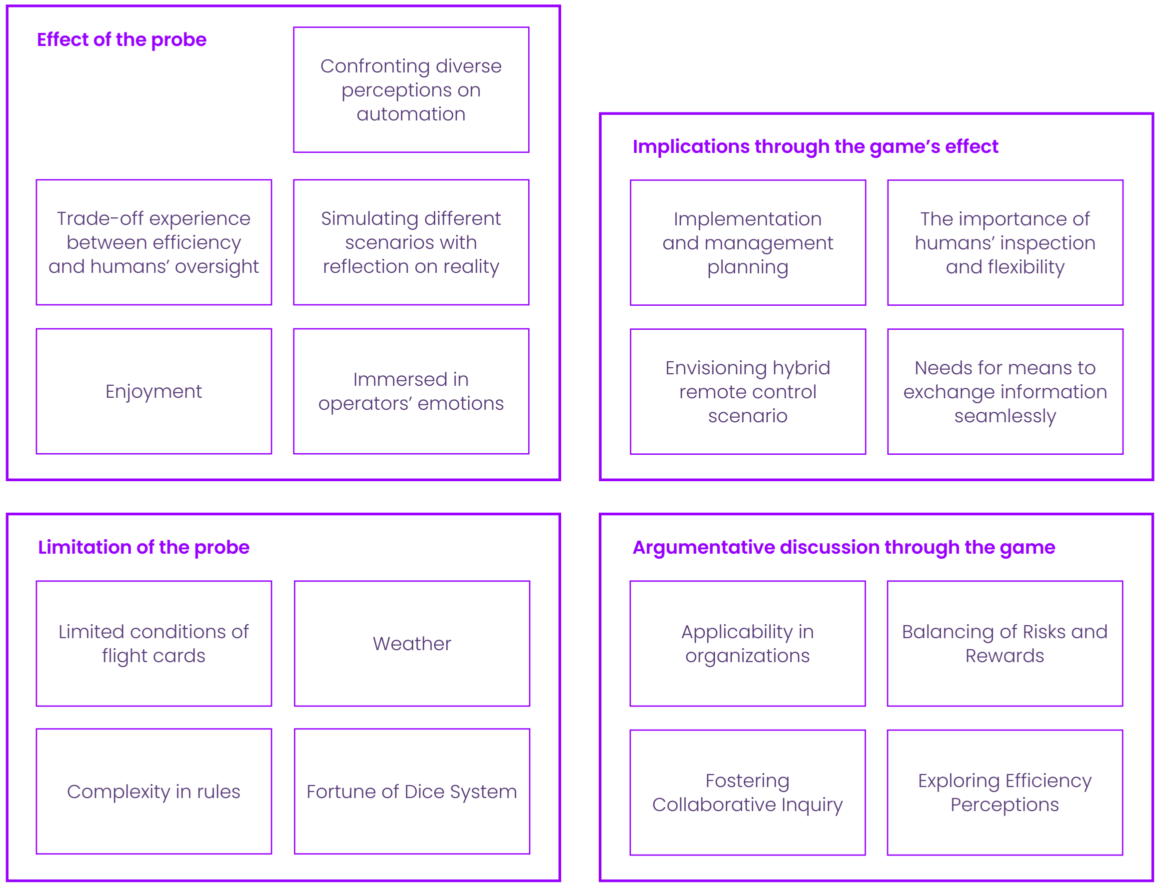
- Reflecting on your choices, what were the most critical points that influenced your decisions?
- What do you think about the different types of PBBs?
- What do you think about the values among employment index, efficiency, and empowerment?
- How could we implement automation technology effectively?

Data Analysis

All the sessions were audio recorded, and the voices were transcribed with some photos taken. Content Analysis with a manifest analysis (Bengtsson, 2016) was used to check if the design goal is achieved from the transcript. The analysis focuses on the words and text that participants used and cluster themes to evaluate the main questions. In addition, pictures were taken, focusing on how participants play on the board, excluding their personalized information, such as faces and clothes.

7.1.2. Results

Four categories were clustered (Figure 7.1): 1) effect of the probe, 2) implications through the game's effect, 3) argumentative discussion through the game, and 4) limitation of the game.



[Figure 7.1. Four clusters from Content Analysis]

1) Effect of the probe

Trade-off experience between efficiency and humans' oversight

Participants were observed to trade off efficiency and humans' oversight as they weighed risks and rewards. Insights from participants' comments indicate a balancing act between these two values, fostered by the game's format. For instance, DM2 highlighted a deliberate acceptance of certain risks within the automated system to optimize efficiency, while concurrently valuing human oversight for assurance. This decision reflects the consideration of efficiency and reliability in the task delegation process. Similarly, O4 expressed that one option might be more efficient regarding costs while the other is more efficient for the overall system. This highlights the trade-off between short-term efficiency gains and long-term holistic performance. Simulating different scenarios with reflection on reality

Simulating different scenarios with reflection on reality

Participants were observed to envision future scenarios by simulating operational situations through the game. DM3 mentioned that the game helped to gain insights into potential challenges and opportunities in future scenarios. O2 imagined the futuristic situation of all bridges becoming APBBs, highlighting the game's potential for insight generation by stating "how I will see the future." Through the game, DM2 could understand the complexities of managing multiple bridges and aircraft types, including the balance between manual and automated bridges. O4 also imagined a possible scenario that controlling the PBB remotely by a ground handler who inspects the aircraft could be more feasible instead of having a separate remote control room, while no one is in the PBB.

> *"Oh, hey, there's only manuals left. Okay, so you can only take one plane because the others are all manual. So then I can only make money with one plane. Yeah, that would be as in real life." DM_2*

Moreover, participants exhibited a tendency to compare simulated scenarios with real-world circumstances, refining their understanding through corrective adjustments. Notably, the game's depiction of weather – rain, fog, and sunny conditions – prompted operators to offer nuanced perspectives, such as the potential inconsequential impact of fog. Further, they spotlighted other climatic conditions like heavy snowfall, lightning, and strong wind.

> *"if there's a heavy snowfall. Snow for combat on the lasers. Yeah. heavy snowfall has something to do with it. Lightning is a complete stop, and also wind, depending on how strong the wind is."_O1*

Confronting diverse perceptions on automation and efficiency

During the sessions, participants expressed their perceptions of automation technology in decision-making, particularly concerning the optimal number of workers and PBB types. Decision-makers often displayed a willingness to explore full automation options, while operators consistently favored manual PBBs, with some even advocating for a hybrid approach. Despite being assigned specific starting points (MPBB, hybrid, or full APBB), all operator participants exhibited apprehensions about complete automation, underlining the significance of human intervention to prevent potential failures. O1 highlighted concerns about relying solely on automation in the face of technical complexities, as O4 also stated that "if you only have an automatic and there's nobody, something goes wrong, you will have a big delay. That's what I think."

> *"Considering the amount of problems we have in bridges I don't think it's a good idea."_O1*

> *"I rather have manual bridge with manual thing (control) than the automatic doing manual. It's not, it's not my favorite." _O4*

However, O2 and O4 also acknowledged that ASs helped increase their efficiency since ASs were quite accurate and useful for operators unfamiliar with PBB operations.

Enjoyment

Most participants expressed enjoyment in playing the game. During session 2, all three participants highlighted that the game not only effectively stimulated critical thinking but also provided an engaging experience. DM2 even expressed, stating, "I would like to play with my dad. He would love this. It would be really fun." In addition, O2 stated that "This is a game to start thinking about making a choice because I made a choice because of our thinking ahead. But that's fun."

Immersed in operators' emotions

A notable observation during the game was that decision-makers empathized with the operator's sentiments when confronted with human failures. DM1 described these failures as "terrible" and "terrifying." Furthermore, participants reflected on the monotonous job characteristics imagining the change in social interactions by increasingly using ASs. Also, O4 expected that the nature of the work would become boring due to increased AS control.

2) Implications through the game's effect

Implementation and management planning

Operators and decision-makers were observed to pose the issues to plan for seamless management, concerning the increased maintenance demands. O2 highlighted the need for new safety measures, while O1 suggested the necessity of extensive sensor deployment to address safety concerns. These discussions indicated the game's potential to inspire proactive planning and decision-making.

> *"And if it's one bridge is okay, but if it's on the 188 bridges, you can understand that something that is mechanical, it will go wrong and sometimes maybe three or four times a day and how will you manage that?" _O2*

The importance of humans' inspection and flexibility

Participants emphasized the importance of humans' inspection and flexibility, which also derived from the primary research as the influential factors of task delegation. Considering the number of workers and location during the game, decision-makers learned the value of inspection, while operators stressed the humans' role in inspection. O1 and O4 highlighted the role of ground staff (i.e. a worker in area A) who inspects aircraft and other procedures as of importance to secure blind spots when the camera fails.

> *"first of all, there also has to be an A (ground staff to inspect aircraft), even if there is because the A is the one most detail always on the ground doing around the thing" _O1*

> *"I also think that this one is a very important one. But you also need like one, one person or maybe two that can drive around if there are some problems with a bridge to go there. extra support."_O4*

In addition, it was preferred for humans to be in a PBB due to the possibility of prompt handling from humans.

> *"because when there's manual and there's people, it can be handled right away." _O4*

Needs for means to exchange information seamlessly

There are needs observed for means to exchange information seamlessly. O4 elaborated on the experience of verbally shouting to the ground staff to watch the connecting status during a camera malfunction. Although they have a handheld, they exhibited their preference for the direct verbal communications because it's quicker.

> *"we have to knock we are the ones that say it is now safe for you to open the doors. Who's going to do that? (if being automatic)" _O1*

Envisioning hybrid remote control scenario

Most participants exhibited inclination to hybrid scenarios, envisioning a symbiotic coexistence between human operators and ASs. DM1 and DM3 speculated that a fully automatic scenario might necessitate swift hiring to manage unforeseen issues, preserving flexibility. Similarly, DM2 also envisioned a remote control situation requiring supervisory oversight.

> *"There always has to be somebody to do manuals because if something goes wrong here and they need somebody to drive over and connect manual because the automatic didn't work." O4*

> *"I believe that we are starting to do remote control, like maybe not remote controlled but maybe remote oversight. That's what I would see here." _DM2*

> *"Within the human operator bridges, one of the sorts of outtakes is, oh, maybe it is still good to have a human in the bridge or human operating because then we can also do the airlines are asking for you and operate a bridge so we can do those airlines"_DM1*

3) Limitation of the game

Fortune of Dice System

There's two different perspectives on the luck system of the dice. Most decision-makers perceived the system as a representative to understand the holistic system although some risks and rewards were argumentative to adjust, reflecting on the real situation. On the other hand, operators were observed to express vulnerability when the scenario led to human failures or technical errors as they showed confidence in operating PBBs as experienced operators who can finish PBB connections within 1-1.5 minutes.

complexity in rules

In general, it was observed that operators felt more difficulty in understanding the game rule than decision-makers. It took more time to introduce the game rule in session 2 and 3 than session 1 only with decision makers. However, they also grasped how the game went, once the first round went.

Limited conditions of flight cards

The limited conditions presented through the flight cards may require room for refinement in the composition of these conditions to align more closely with real-world scenarios. In certain instances, players with full APBB options were unable to select the second flight card due to manual requirements or the need for a person in the PBB. However, participants also acknowledged that automating all systems may accommodate only a limited number of planes, and it could be one of the scenarios that organizations should recognize and consider.

Weather

Weather conditions were deemed a central influence in gameplay, as specific conditions influenced AS success rates. However, participants did not extensively experience the full dynamic range of weather effects, particularly in instances of rain or fog.

4) Argumentative discussion through the game

Applicability in organizations

In the session where decision-makers were involved, the potential of the game was mentioned regarding applicability for organizations that the game's mechanics can offer practical possibilities to integrate into their real-world practices. DM4 proposed a compelling application by utilizing the scenario probabilities to analyze operational efficiency through empirical testing, potentially yielding valuable data insights at a glance. DM1 emphasized the game's capacity to facilitate a "cross-dimensional exercise," allowing stakeholders to grasp the potential impact of robotization and associated future risks. DM3 also highlighted the importance of post-scenario explanation cards, enabling players to delve into the underlying rationales behind rewards and risks, thereby enhancing their understanding and learning. These perspectives collectively illustrate the potential for the game to serve as a valuable tool for strategic decision-making, risk assessment, and fostering comprehensive insights in the realm of HAC within airside operations.

Fostering Collaborative Inquiry

The game used during the session encourages participants to ask each other questions. Notably, decision-makers were observed to be more proactive in posing questions than operators, particularly in session 2 (only with DM) and session 3 (mixed group). This observation suggests that the game allows decision-makers to effectively facilitate meetings between the two stakeholder groups and formulate detailed questions through the game simulation regardless of the researcher's prepared questions.

Balancing of Risks and Rewards

Participants were observed to consider the game's balance of risks and rewards. They acknowledged the potential for increased risk with automation, hinting at an underlying caution. DM2 expressed the complexity of risk evaluation, highlighting the nuanced nature of risk perception and the challenge of quantifying it. DM1 brought attention to the influence of environmental factors like fog on automation, suggesting potential difficulties in such conditions due to automated reliance on equipment like Lidar. They contrasted this with human reliance on visual cues, implying that manual operation might prove more resilient. The penalties to pay in human failure (collision) were perceived as low for DM1, while DM2 acknowledged that the failure from full automation may have bigger risks, imagining passenger disembarkation failure, which may lead to huge risks. They emphasized that while the probability of such an incident might be low, its potential consequences could entail significant costs.

Exploring Efficiency Perceptions

Regarding efficiency, distinct perspectives emerged regarding efficiency perceptions. Operators generally regarded manual control as swifter, rooted in their operational experience. O1 emphasized human capacity for three-dimensional manual control, contrasting it with the limited unidirectional capability of automation.

> *“I like manual because automatic is too slow” _O3*

> *“I had to put it on a manual after it started, I think I'm quicker. ... Because it's alternated by to make it automatic. If I'm starting to do the manual, it's so slow, no exaggerating.” O4*

On the other hand, decision-makers recognized the efficiency potential of automation, aligning with labor cost considerations. DM3 noted the potential interrelation between empowerment and efficiency, indicating that the level of empowerment or delegation to ASs may impact the system's overall efficiency. DM1 also highlighted the pros and cons of maintaining the number of workers regarding a demand for people in reality.

7.1.3. Takeaways

Organizations can utilize the game's diverse simulations to explore possible futures and consider various factors, challenges, and opportunities in HAC implementation. Valuable insights from player experiences and reflections can inform decision-making and planning processes for HAC's future.

Can the design lead participants to confront **different perspectives** of the decision-making process in task delegation?

- Confronting diverse perceptions on automation
- Immersed in operators' emotions
- Exploring Efficiency Perceptions

The game mechanics guided participants to formulate decisions reflecting their perceptions of automation, revealing varying attitudes towards delegation. The hands-on nature of the game facilitated decision-makers' empathy with operators, whereas operators gained insight into management challenges. Operators focused on game realism, comparing it to current operations, while decision-makers aimed to improve mechanics and assess scenario values. Both aspects can be relevant in ASs implementation.

Diverse efficiency viewpoints also emerged; operators favored manual control for speed, while decision-makers valued automation's efficiency potential considering labor costs. They raised the issue of workforce optimization in demand fluctuations, highlighting different interpretations of operational efficiency and indicating the needs for more organizational discussion.

Interestingly, while distinct sessions showcased all the meaningful insights, only the mixed-group session demonstrated self provoked exchange of questions to comprehend differing viewpoints.

Can the design provoke participants to **confront two different values** between the importance of reliability assuring a holistic situation and the importance of efficiency by accuracy?

- Trade-off experience between efficiency and humans' oversight
- Balancing of Risks and Rewards

The probe can prompt participants to explore the interplay between reliability by humans and efficiency by AS's accuracy, taking into account limited resources, risks, and rewards. The quotes from participants indicate a balancing act between these two values, and the game format allows them to explore this dilemma more deeply.

Can the design help organizations **envision possible/probable scenarios** of how HAC may be changed **with different variables**?

- Simulating different scenarios with reflection on reality
- Envisioning hybrid remote control scenario
- The importance of humans' inspection and flexibility
- Needs for means to exchange information seamlessly
- Implementation and management planning

Participants could envision future scenarios through simulated operational situations in the game, highlighting its insight-generating potential for understanding challenges and opportunities. The game prompts operators and decision-makers to consider how to address seamless management planning, safety measures, and sensor placement, highlighting the importance of human inspection and flexibility.

How could the design be practical for decision-makers to **open up discussions and make decisions** in task delegation?

- Enjoyment
- Applicability in organizations
- Fostering Collaborative Inquiry

The design can serve as a means to facilitate discussions on collaborating with ASs in an engaging manner. Participants expressed enjoyment and highlighted the game's capacity to stimulate critical thinking, positioning it as an effective icebreaker for stakeholder meetings or workshops. It can encourage collaborative inquiry, especially evident from decision-makers, fostering in-depth discussions with operators. They also recognized the game's practical value for real-world organizations, suggesting using scenario probabilities for operational efficiency analysis and exploring robotization and associated risks. Thus, the game can potentially encourage open discussions, support decision-making, simulate risk assessment, and offer insights within airside operations.

8. Discussion

The chapter introduces key findings to answer the research questions from the literature study, context research, primary research, and evaluations

8.1. Implications

8.1.1. Influential factors in task delegation

Multiple perspectives should be considered to ensure a holistic understanding of task delegation in HRI or HRC. Reviewing the prior literature, seven influential factors were selected to identify which tasks can be delegated to ASs and which tasks humans should perform: **Time and Space, Levels of Autonomy (LoA), ASs' task specification, team composition, capabilities, human preference, and costs.** These seven factors were the fundamentals to shape the primary study in this thesis.

RQ1.
What influential factors can be considered in task delegation between humans and ASs for effiacient airside operations?

Furthermore, the primary research uncovers 12 thems with four dimensions: **1) Challenges of HAC in operations, 2) Working conditions and limited resources, 3) Preference for ASs over Humans, and 4) Preference for Humans over ASs.** These insights lead to the development and testing of a speculative board game, acting as a probing tool. Based on these findings, a roadmap was outlined which will be described in the following discussion.

Expanding Task Specification with Tour Additional Tasks

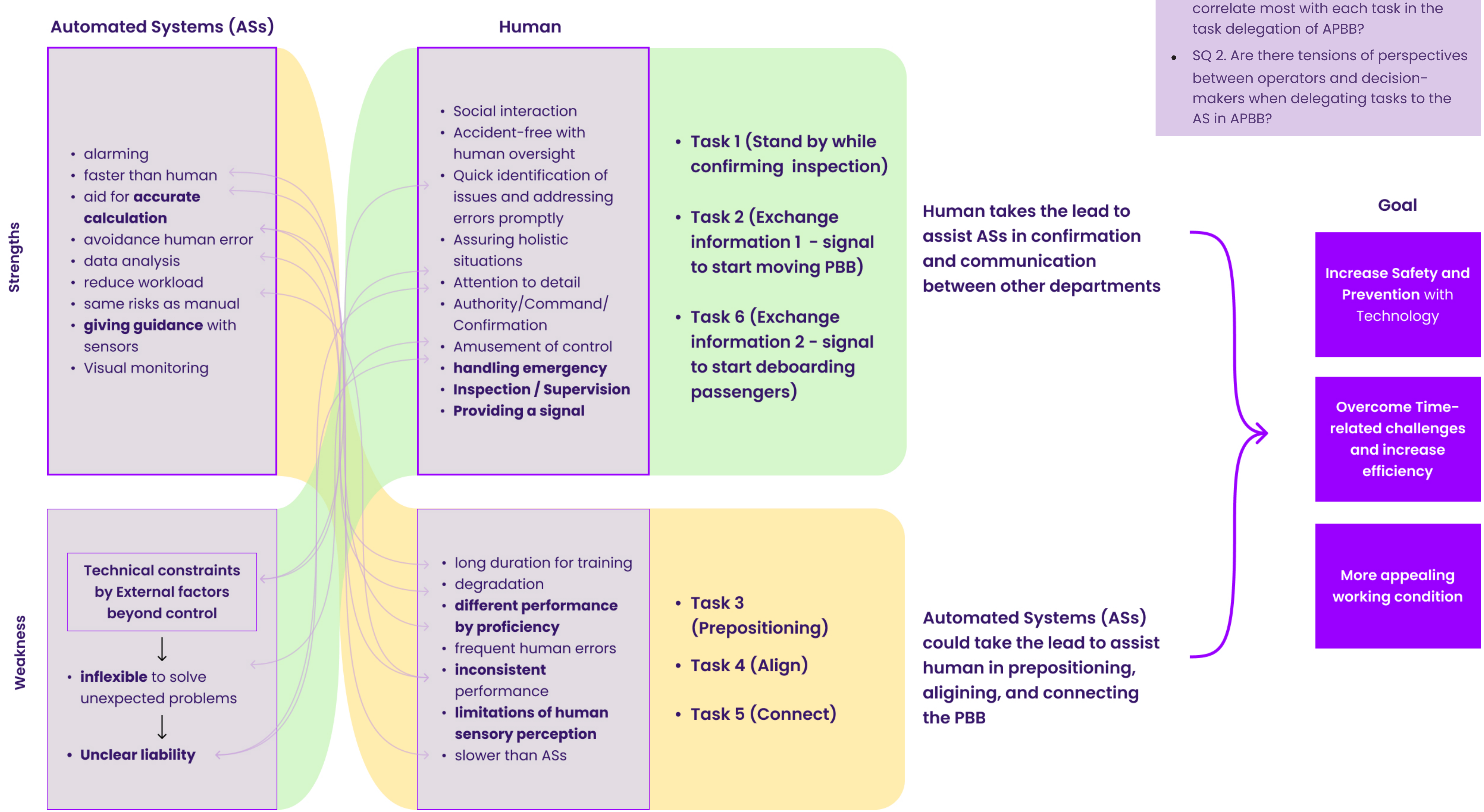
The synthesis of insights from both the literature study and contextual research contributes to the identification of four additional ASstasks to be considered. Complementing the existing eight tasks highlighted in prior research, the newly introduced tasks include aligning, plugging, integration, and generation. It's noteworthy that while the term "manipulation" in previous research encompasses elements of aligning, plugging, and integration, the clear distinction is crucial due to the differing behavioral patterns and cognitive processes exhibited by operators in each distinct task.
I hope that this added classification can aid in more precise exploration while ensuring a comprehensive understanding of the AS's work in the airside task.

8.1.2. Tasks that can be delegated to ASs vs. tasks that humans should take

Synthesizing the strengths and weaknesses of humans and ASs as seen in Figure 8.1., the results indicate the distinction in the nature of tasks in discerning those best suited for ASs delegation and those warranting human control. High-precision tasks, such as prepositioning, aligning, and connecting, perceived as requiring higher effort, expertise,

RQ2
In the transition of different PBB operation types, how can we better understand which tasks can be delegated to ASs, and which tasks humans should perform?

- SQ 1. How do the influential factors (e.g., human preferences, capabilities) correlate most with each task in the task delegation of APBB?
- SQ 2. Are there tensions of perspectives between operators and decision-makers when delegating tasks to the AS in APBB?



[Figure 8.1 Strengths and weaknesses of humans and ASs to achieve goals] and risks than other tasks, have been identified as potential candidates for delegation to ASs from the response trend from the survey and qualitative data. These operations necessitate meticulous calculations and excel within AS capabilities, offering enhanced efficiency and reduced time pressure. Nevertheless, human supervision remains integral due to the intricate operational nuances.

As for the ASs' strengths, ASs exhibit potential strengths in "assuming responsibility," "precision," "endurance," and "speed," as indicated by prior research. In assuming responsibility, the APBB is capable of alarming, visual monitoring, and sensor-guided navigation. ASs also excel in precision by mathematically calculating distances, outperforming humans' sensory reliance. Furthermore, their infinite patience counters time pressures, a leading cause of human errors in PBB operations. This affords ASs more consistent performance than humans, with the potential for faster operations.

However, recognizing their limitations is crucial to optimizing AS potential, complemented by human strengths in "flexibility," "action and movement planning," and "sensorimotor abilities." While AS precision can be compromised by unpredictable factors like environmental conditions, weight shifts, sudden obstacles under the apron, or varying parking positions, resulting in extended resolution times and lower operational efficiency, human adaptability remains pivotal. Their holistic understanding and flexibility within the dynamic airside environment help prevent unforeseen accidents and address nuanced issues through their sensorimotor abilities.

In this regard, tasks requiring clear communication and meticulous inspection can align better with human management. Tasks such as "Stand by while confirming inspection," "Exchange Information" exemplify areas where human intervention outperforms ASs. Effective "exchange information" is pivotal for liability, safety, and reliability. Many operators expressed reservations about ASs' suitability for tasks involving information exchange due to communication's critical nature and potential unforeseen circumstances. These tasks can also extend to higher-level communication, necessitating stakeholder coordination for successful PBB implementation.

Furthermore, this research uncovers unexplored human unique strengths in 1) exchanging information through confirmation and 2) deriving enjoyment from work through social interactions. This interaction involves not just capability but encompass task accountability. The responsibility to exchange information may pose execution challenges for ASs. Additionally, working conditions with enjoyment are crucial for human involvement. Survey data suggests a potential correlation between motivation, trust, and humans' inclination to assume control. This interplay, encompassing information exchange and social interaction, underscores operators' multifaceted roles extending beyond data exchange, emphasizing their broader influence in airside operations.

Tensions between Decision-makers and Operators

The analysis of primary research data unveils distinct perspectives between decision-makers and operators. Concerning efficiency perceptions, decision-makers tended to emphasize maintenance and operations, while operators are likely to focus more on their performance. Notably, in the context of task 6, involving the exchange of signals with flight crews, decision-makers expressed optimism about automation feasibility for realizing remote control scenarios, whereas operators expressed doubts. This skepticism stems from considering additional tasks that operators need to complete upon entering a PBB, such as guiding passengers based on flight origins, which extends beyond the scope of task 6.

Benefits and Risks of Different PBB Types

The insights from the analysis yield a comprehensive understanding of the benefits and risks of four different PBB types regarding performance, reliability, and labor costs (Figure 8.2).

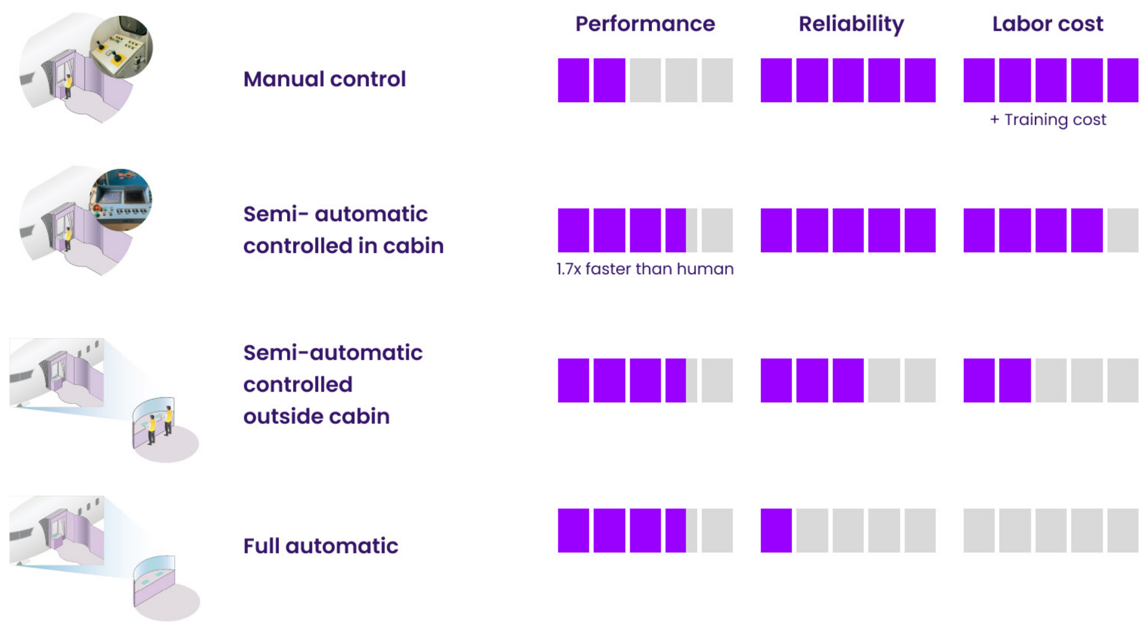
Type 1 - Manual: While showcasing the lowest performance metrics and highest labor costs, this type exhibits the highest reliability levels assuring safety. Its dependable operational consistency can be attributed to human control, but this reliability comes at the expense of operational efficiency with training labors.

Type 2 - Semi-Automatic Control Within PBB: This PBB type demonstrates a performance enhancement, operating on average at 1.7 times the speed of manual control, while maintaining comparable reliability levels. Labor costs slightly can decrease, as lower the training investment in automatic control is expected than the manual one.

Type 3 - Semi-Automatic Control Outside PBB: Similiar in performance to Type 2, however, this type may decrease reliability. The operator's location outside the PBB could lead to errors stemming from blind spots. Despite this, labor costs may be reduced. With one operator managing multiple PBBs simultaneously, greater resource efficiency can be achieved.

Type 4 - Full Automatic: Offering similar performance capabilities to Types 2 and 3, this type significantly lowers both reliability and labor costs. The trade-off here is that reduced reliability may lead to notable errors or collisions, leading to elevated costs. Nonetheless, significant labor cost savings can lead to significant budget savings, an important consideration in situations of labor shortages.

Therefore, balancing these three pivotal aspects - performance, reliability, and labor costs - is imperative. Organizations must strategically weigh these factors when contemplating the integration of ASs and the optimal allocation of human resources.



[Figure 8.2. Benefits and risks of different PBB types]

8.1.3. Implications from evaluation of the game PBB

The designed game functions as a valuable tool for organizations, enabling a balanced perspective between reliability and efficiency by exploring diverse futures, assessing challenges, and identifying opportunities linked to ASs implementation. Through various simulations, the game yields insights for making decisions and planning for the future of HAC in airside operations.

The evaluation demonstrates the game's potential to envision the impact of HAC under various variables. Simulations prompt participants to contemplate future scenarios, aiding in identifying challenges and opportunities. This capacity encourages discussions about management planning, safety measures, sensor placement, and the role of human inspection and flexibility in these envisioned scenarios.

The hands-on nature prompts participants to confront different decision-making perspectives in task delegation by visualizing choices and their consequences on the board. As players make choices reflecting their perceptions of automation, the game unveils contrasting attitudes towards delegation. It allows decision-makers to empathize with operators emotions and grasp the intricate operations, while encouraging operators to consider maintenance isses when the number of APBBs increases.

Furthermore, the game design stimulates discussions about two key values: the significance of reliability for holistic operations and the importance of accuracy-driven efficiency. Guiding participants to navigate the balance between risks and rewards, the game facilitates thorough exploration of this dilemma and fosters dialogue and strategic considerations regarding automation and task delegation.

Serving as a practical tool for decision-makers, the game can be an engaging platform to initiate discussions about AS collaboration. Its stimulating nature makes it effective as an icebreaker for stakeholder meetings or workshops. The design also fosters collaborative inquiry, particularly among decision-makers who actively engage in discussion with operators. Moreover, decision-makers acknowledge the game's applicability in real-world contexts, suggesting scenario probabilities for analyzing operational efficiency and exploring robotization implications and associated risks.

In essence, the game's potential lies in encouraging open discussions, aiding decision-making, simulating risk assessment, and providing comprehensive insights in HAC.

What would the scenario be if both reliability and efficiency are equally important?

In the scenario where both reliability and efficiency are equally imperative, organizations will need to adopt a strategy that combines cutting-edge ASs with highly skilled human operators. Using advanced ASs may increase accuracy and speed under humans' supervision. When it comes to sudden errors, highly skilled operators can swiftly intervene to modify the mode and successfully conclude the task, complementing the ASs' performance.

However, maintaining experienced operators who can match the capabilities of ASs might pose challenges due to the associated costs and time required for their training. In addition, instances of critical errors that surpass operators' capabilities could necessitate the involvement of technicians, leading to extended resolution periods and potential reductions in efficiency.

8.2. Future vision through the roadmap

The roadmap offers an efficient framework for comprehending the evolving landscape of task delegation between humans and ASs with influential factors to be considered. It presents a guided path for organizations to grasp the intricate nuances of the transition and transformation process.

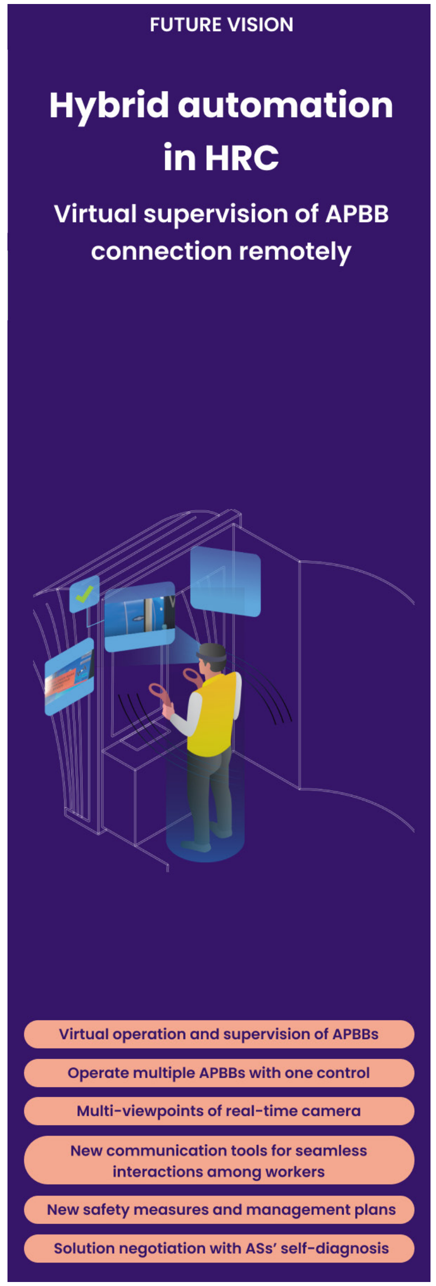
Future Vision

A comprehensive future vision (figure 8.3) for RSG by the year 2050 has been formulated, drawing from integrated findings from the literature study, context research, in-depth interviews, and survey findings. This projection aligns with RSG's goal of operating sustainable airports worldwide by 2050.

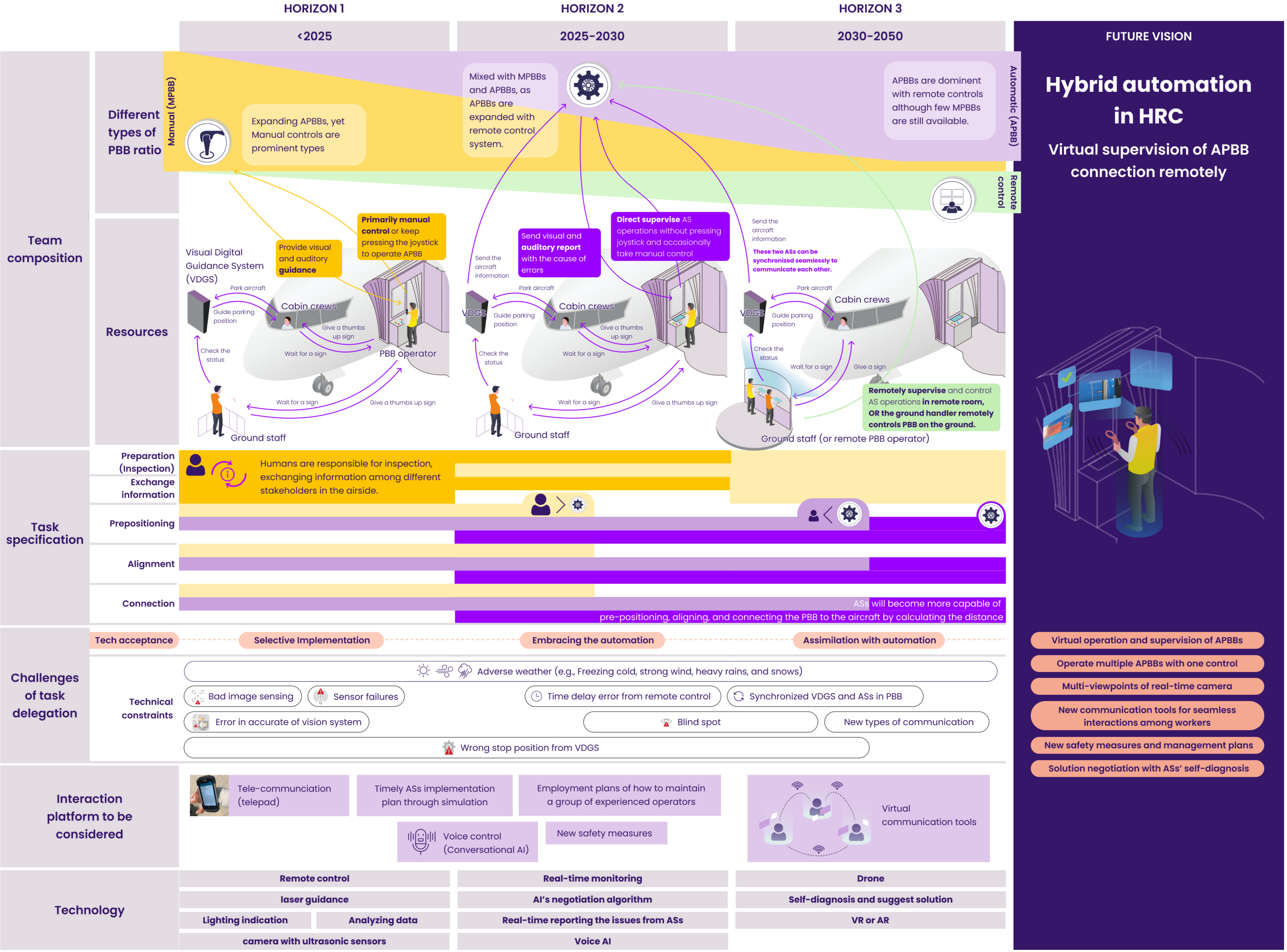
RSG should aim to create a hybrid Human-Automation Collaboration (HAC) under humans' holistic oversight, integrating virtual remote control into operations. In this approach, humans will assume a pivotal role in preparatory and communication tasks, ensuring clear status updates for stakeholders, thus preventing incidents. New communication tools, potentially using VR/AR, will enable seamless interactions among workers.

Meanwhile, ASs will specialize in precise and swift PBB connection. Real-time multi-viewpoint cameras will provide an all-encompassing operational view, synchronized onto virtual screens, allowing remote real-time oversight from any location they are situated. In case of errors, ASs will autonomously diagnose and suggest solutions, allowing humans to comprehend the situation, negotiate, and promptly address the issue. In addition, new safety protocols and strategies will be developed collaboratively with stakeholders, including ground handlers, airlines, and the government.

To realize this vision, the roadmap (figure 8.4) outlines five sections - team composition, task specification, task delegation challenges, interaction platform considerations, and technology - along with a three-horizon timeline for PBB operations management enhancement. This roadmap guides RSG towards the desired future while offering an overview of PBB transition phases.



[Figure 8.3. RSG's Future vision for APBBs impelemntation]



[Figure 8.4. RSG's roadmap of APBBs implementation]

Horizon 1 - Selective implementation

The first horizon will be the selective implementation of APBBs where MPBBs will still be maintained as prominent types of PBBs in RSG while expanding APBBs. Humans will play a central role in all types of tasks in PBB operations. In this phase, PBB operators will primarily maintain manual control or use joystick inputs to operate APBBs, with ASs providing visual and auditory guidance. Humans also will retain responsibility for aircraft inspections and the exchange of critical information among airside stakeholders.

With the telepad remaining the primary interaction platform, explorations into added enhancements are expected, including voice control facilitated by conversational AI. This verbal control can streamline communications, particularly during manual PBB control scenarios.

From a technological standpoint, the development and deployment of lasers and ultrasonic sensors are relatively anticipated to be straightforward soon. Detailed data analysis will guide their implementation, ensuring efficiency. Moreover, the recent advent of remote control technology should be explored, as its integration could yield substantial benefits in enhancing operational efficiency and control.

Thus, Horizon 1 sets the stage for RSG to integrate ASs while concurrently strengthening its adaptive capabilities to address emerging challenges and harness evolving technologies.

Horizon 2 - Embracing automation

Moving into the second horizon involves a deeper adoption of automation, with more APBBs introduced to align with current MPBB numbers. Operators will shift to direct supervision to AS operations, reducing the continuous manual joystick control within PBBs. Instead, manual intervention will occur intermittently as needed.

The nature of tasks of humans and ASs tended to be a plateau; however, the transition of responsibility will be found in prepositioning, aligning, and connecting PBBs, which can be delegated to ASs' lead with humans' assistance. These tasks are envisioned to be entrusted to ASs, with humans offering supportive oversight. These tasks are envisioned to be entrusted to ASs, with humans offering supportive oversight.

Furthermore, RSG will need to start building new safety measures, a timely ASs implementation plan, and an employment plan for sustaining highly skilled operators. In the context of safety measures, effective communication and negotiation with various departments will be vital. As different departments may develop separate systems, ensuring compatibility and integration is crucial to prevent any limitations on AS capabilities due to disparate underlying systems. The ASs cannot adjust to other new systems that are not integrated and stop their function. The potential challenge of task allocation dynamics between humans and ASs, stemming from the increasing number of APBBs, necessitates a flexible approach to operational planning.

Therefore, a proactive approach to identifying and validating transformative technologies is recommended for RSG during this phase. The integration of a real-time monitoring system capable of promptly reporting AS issues can ameliorate the time lag associated with remote control scenarios. Additionally, the integration of AI-driven negotiation algorithms is worth considering to develop a robust conversational AI, streamlining communication and interaction within the operational context.

Horizon 3 - Assimilation with automation

The third horizon symbolizes assimilation with automation, reflecting an environment where stakeholders increasingly embrace automation technology. With an optimized remote control center, operators can supervise or control APBBs remotely. Delegation to ASs in prepositioning, aligning, and connecting is heightened, with human assistance enhancing their lead role.

The remote control system may allow for greater operatioinal flexibility. Operators can remotely control multiple systems, leading to resource optimization and streamlined utilization of automated systems as operators do not have to detour the gates.

However, due to the highly secured regulation and liability issues, operators are anticipated to maintain a certain level of control with the assistance of automated systems, particularly in critical communication and preparatory tasks, to prevent potential incidents. For instance, signaling a cabin crew with a thumbs-up sign after a PBB connection will necessitate innovative communication tools or platforms leveraging cutting-edge technology to ensure human reliability in remote scenarios.

Furthermore, if the challenge of blind spots remains, the integration of drones could offer a potential solution to transform operational capabilities. However, it is crucial to acknowledge that incorporating drones introduces an additional layer of complexity, as they would require dedicated operators or ground handlers to control them. This presents a trade-off between addressing blind spots and the added task of managing drones, highlighting the need for a comprehensive assessment of the benefits and challenges associated with this approach.

In this regard, the future vision suggests a hybrid scenario in that ASs can cooperate with humans in operations. The practical realization of full automation without human oversight remains uncertain in the real world.

8.3. Contributions

8.3.1. To the Academia

Integrating Empirical and Theoretical Insights: A holistic Exploration of HAC in Aviation

The primary contribution of this research lies in its unique approach of merging empirical insights with theoretical perspectives. Within the mobility community, particularly in the aviation industry, this study offers valuable empirical findings from the AAO context. Through in-depth interviews and data analysis, the study illuminates the viewpoints of both operators and decision-makers and provides 12 thematic themes with four diemensions regarding task delegation. By expanding the understanding of benefits, challenges, and considerations associated with ASs in aviation settings, this research enriches the existing body of knowledge with tangible evidence and context-specific understanding.

This research further contributes by offering not only theoretical insights but also empirical validation of influential factors within task delegation in the Human-Computer Interaction (HCI) community. The influential factors in task delegation derived from a comprehensive literature study were combined with the themes from qualitative data of in-depth interviews and quantitative data from a structured survey. This combination enables a deeper exploration of task delegation dynamics, particularly resulting in the importance of humans' role in exchanging information among stakeholders and trends of task delegability regarding human preferences.

By integrating empirical data into the existing theoretical factors, this study provides a well-rounded perspective with themes, enhancing the deeper understanding of HAC and its implications for operational efficiency, safety, and decision-making.

A means to access task delegability combined with two frameworks from prior research (Beer et al., 2014; Lubars & Tan, 2019)

The development of a sensitizing tool (depicted in Figure 4.2. on page 48) designed for in-depth interviews contributes to providing researchers with a means to assess task delegability across varying levels of autonomy.

This tool is complemented by the integration of two frameworks: the LoA from Beer et al. (2014) as seen in Figure 2.4. (pg. 21) and degree of delegation (Table 2.4., pg. 26).

8.3.2. To RSG

Holistic Understanding of HAC

The research provides organizations with a comprehensive understanding of task delegation between human operators and automation systems in airside operations, including influential factors in task delegation, and the strengths and weaknesses of humans and ASs. This understanding involves combined knowledge of theoretical concepts and practical insights, which can assist in decision-making in task allocation and enhance overall operational performance.

Decision-Making Support in Task Delegation

The study contributes to organizations' decision-making processes by shedding light on effective operational management plans for task delegation between human operators and automation systems. The empirical evidence with real-world insights offers an understanding of the factors to consider when implementing APBB and the allocation of tasks between humans and ASs. Through the PBB game, organizations can fine-tune their approach to task allocation, optimizing operational efficiency while ensuring safety and reliability.

Scenario Exploration and Future Vision as a Guideline

The speculative probe and the developed roadmap offer organizations a structured approach to envisioning the future of their operations. The scenario based game play allows stakeholders to experience in multiple scenarios in an engaging manner. Moreover, through the future timeline horizons in the roadmap, organizations can explore various possibilities and challenges that arise with the implementation of automation with actionable management plans. The roadmap's step-by-step approach aids organizations to gradually adapt to the changing automation landscape and to formulate long-term plans that align with their goals and aspirations.

Tool Support

The research introduces the PBB game as a valuable tool for facilitating participatory workshops in organizations' automation projects. Visual aids used during the study were also noted as helpful resources within RSG. Moreover, the AAO journey map (Figure 3.3) and the sensitizing probe (Figure 4.2) show potentials to aid organizations' comprehension of operational procedures related to HAC. The team members at the Innovative Hub expressed their intent to integrate these visual tools as an internal resource. Figure 3.3 enhances understanding of airside operation procedures, focusing on human factors, while Figure 4.2 aids engagement with stakeholders on ASs. Based on these tools, an internal framework for comprehending automation and human tasks was developed internally.

8.4. Limitations

By combining empirical and theoretical insights, this study offers future-vision guidelines for a comprehensive understanding of task delegation within HAC, with a specific focus on APBBs. However, there are limitations to consider.

8.4.1. to Academia

The Process of Scoping Down

The process of scoping down was challenging, with suitable reasons to delve into. The objective approach was tried by having numerical weights on the priority within RSG. However, thorough criteria to set up was out of scope; therefore, the maturity of automation in AAO and frequency of specific actions (positioning) were mainly concerned for the final decision.

Sample Size and Type

To enhance the representativeness and reliability of future studies, it is recommended to increase the sample size and strive for a balanced participant distribution. In the current research, due to time constraints and challenges related to operators' working schedules, recruiting a sufficient number of participants was challenging, resulting in a limited participant pool. This can lead to the emergence of trends rather than broadly generalized knowledge. Moreover, the survey faced limitations due to the scarcity of decision-makers experienced in APBB implementation, hindering a comprehensive comparison with operators' responses.

Moreover, efforts to balance the sample type could be beneficial. At the project's outset, involving a diverse array of automation experts beyond PBBs could provide broader insights and guide project directions. Furthermore, during the evaluation sessions, difficulties in participant availability led to a focus on a specific group, affecting the sessions' diversity. In this context, obtaining a larger sample from varied departments could lead to more comprehensive evaluations.

To ensure a broader perspective and more robust conclusions, future studies could target a more extensive and diverse range of decision-makers and operators within the aviation industry. This approach would not only strengthen the findings' validity but also promote a more holistic understanding of automation implementation.

Interview Format

The interview format could be more engaging. Since interviewees are not only from the Netherlands but also from other countries, having an online interview format was inevitable. Although the digital intervention was useful for them to explain detailed tasks and explain by showing the overall flow of the tasks, there could be room for improvement, such as simplifying visualization. In addition, the experience with the Miroboard could have more interactions.

Subjectivity in the Data Analysis

It is essential to acknowledge the potential impact of a researcher's biases on the analysis. As one of the main research methods is the qualitative data analysis. With RTA, the researcher may have his/her preconceived notions or beliefs, which can inadvertently influence how to interpret the data collected during interviews and observations. Additionally, participants themselves may have their own biases and perspectives that could shape the information they provide. It is worth noting that the participants' demographics also indicate a potential bias, with five out of six participants being male. Also, one of the participants joined the interview twice (i.e., expert interviews and in-depth interviews).

To mitigate this concern, data triangulation was implemented as part of the research design. By collecting data from multiple sources, such as interviews, shadowing, and surveys, the validity of the findings can be enhanced. Comparing information from different sources allows researchers to gain a more comprehensive understanding of the topic and minimize the impact of individual biases.

While RTA allows for interpretive flexibility and data triangulation has been implemented, additional measures must be taken to reduce researcher bias and bolster the data's reliability. Rigorous data collection with explicit sampling and analyzing data with more than one researcher should be employed to strengthen the credibility of the research findings.

Validation of Sensitizing Tool (Figure 4.2.)

Although the merging of two distinct frameworks to create a method for gauging delegation levels based on autonomy represents a valuable contribution, comprehensive validation remains a necessary enhancement. Employing appropriate questionnaires to assess the usability and effectiveness of the tool could further refine its utility.

8.4.2. to RSG

Accessibility of the PBB Game

The PBB game presents a challenge in terms of accessibility. In the evaluation, it was observed that most operators tended to have more difficulty in understanding the rule to start, while sessions with decision-makers went smoothly. This variance in rule comprehension could stem from multiple factors. One of the reasons could be the complexity of game mechanism, that requires tactical plays with dynamic elements such as employment index, empowerment index, and efficiency index. Age range differences could be another dimension to this variance, as operators are typically in the 40s and 50s, while decision-makers represent younger generations potentially more familiar with board games. Another contributing factor could be the varying job roles of operators, focused on daily task execution, compared to decision-makers' broader perspective involving extensive planning and long-term strategies.

To address these challenges, it is recommended to conduct the game within facilitated workshop settings with the involvement of a facilitator, initially simulating how the game works to aid participants' understanding. In addition, organizing mixed group sessions to complement each other with different rule understandings based on job characteristics has the potential to increase the value of the game by fostering comprehensive insights from multiple perspectives. Once participants overcome the initial learning curve, the game becomes intuitive and enjoyable. However, within organizational contexts, the inclusion of a facilitator for workshops with the game remains an important consideration.

Furthermore, the game's duration poses a challenge for practical implementation within organizations due to their demanding office hours. The approximately 1 to 1.5-hour gameplay, excluding the time needed for rule explanation, might be perceived as a significant time commitment.

To address this limitation, a roadmap has been devised to the insights gathered from this study concerning the evolving landscape of task delegation, offering a comprehensive view of the anticipated future vision in task delegation. While the roadmap provides a condensed overview of the insights, conducting workshops centered around the PBB game can remain invaluable. These workshops enable stakeholders to interact with scenarios in an engaging manner, fostering a deeper understanding and practical engagement with the concepts presented in the study.

Data Limitation in the PBB Game

The game design relied heavily on internal data from RSG; however, some are defined from empirical data, which subjectivity may influence determining the dice possibilities. In addition, it should be noted that some of the data may be outdated or less reflective of the current reality, especially considering the impact of the COVID-19 pandemic. The experiment had to be postponed, leading to the use of data from 2018. Additionally, certain scenarios in the game were based on future-oriented speculations, resulting in limited available data.

Despite these limitations, the tool can still be valuable for organizations by updating the data, adjusting the probabilities associated with the dice, and iterating on the game. By doing so, the tool can enable a more realistic exploration of future scenarios and facilitate open discussions among multiple individuals.

The Game Mechanism

The game mechanism of the Fortune of Dice system, while providing an element of chance and unpredictability, has its limitations. It might introduce an excessive level of randomness that could overshadow strategic decision-making, where participants, particularly operators, posed issues during the play. As most of the operator participants have over 15-year experienced PBB operations, they tended to more trust in their own ability than ASs, aligning with MPBB preference. Thus, Frustration moments were observed that some participants who might felt that their choices are overly influenced by luck.

Similarly, the representation of weather conditions within the game, including rain, fog, and sunny weather, while adding realism, might have limitations in adequately simulating the impact of weather on automated systems and operations. The game's focus on a limited set of weather conditions might not encompass the full spectrum of real-world weather challenges that impact airport operations, which could lead to an incomplete understanding of the complexities and implications of weather-related disruptions.

The limitations of the flight cards within the game also deserve consideration. While the flight cards aim to introduce variability in operational conditions, they might not fully capture the diverse range of factors that affect real-world flight operations. The predefined conditions on the flight cards might not align perfectly with the dynamic and context-sensitive scenarios that operators and decision-makers encounter in actual airside operations. For instance, a refinement could involve adapting the number of flight cards based on the proportion of planes requiring manual operation. Similarly, a similar approach could be employed to determine the prevalence of airlines mandating operator presence in area B, thereby facilitating a more accurate representation of these parameters within the game mechanics. Therefore, such adjustments would enhance the game's fidelity to actual operational complexities.

These limitations collectively highlight the need for a delicate balance between realism and simplicity within the game's mechanics. However, finding the balance can be an opportunity for organizations to have a valuable discussion about the issues for better management.

Validation of the Roadmap

The roadmap was constructed to encapsulate the findings of this study; however, there are areas for future research to consider. Firstly, validating the roadmap remains an improvement, so the iterative validation process within RSG could be enhanced. Additionally, exploring potential technologies for integration with PBBs and other ASs in airside operations presents a promising avenue. While the future vision includes the integration of VR/AR technology based on overarching trends, an in-depth analysis of these technology trends could enhance the robustness of the envisioned scenarios and enhance the credibility of the roadmap's projections.

8.5. Future works

8.5.1. In general

The exert interviews from context research provides 8 themes with four dimensions, and primary research also provides 12 themes across four dimensions, regarding task delegation between humans and ASs. Despite the improvement of the themes, enriching these themes with saturated data from other domains in the airside could contribute to the development of a comprehensive theory for further research.

Additionally, given the focus on human factors in this study, delving deeper into the psychological and sociotechnical dimensions of human-automation interaction could prove valuable in ensuring the effective integration of automated systems. This entails investigating factors such as trust, workload distribution, and communication interfaces to optimize the collaborative dynamics between human operators and automated systems.

In the progress of the research, numerous intriguing perspectives and insights emerged from the interviews, warranting further investigation. To advance the research in this field, the following research questions can be explored:

- What measures or strategies are required to address errors and failures in each type of PBB control, considering the specific challenges and characteristics of each system?
- How do the mental and physical demands of operating MPBBs and APBBs differ? What cognitive or physical factors affect performance?
- How does work proficiency in operating ASs influence task delegation?
- Do operators prefer diverse experiences or specialization? How do these preferences impact training and workforce management for manual and automatic operations?

Addressing these questions could deepen understanding of external influences on PBB and APBB performance, error mitigation strategies, operator requirements, time efficiency benefits from automation, and preferences for task variety or specialization.

8.5.2. To RSG

Enhance Accessibility of the Probe

To increase accessibility of the PBB game, developing an online version of the game is recommended, particularly for meetings involving participants from different organizations with hybrid working styles. While this study chose physical elements for intimate interactions between players, it's important to consider that many of RSG's meetings are structured as hybrid meetings. However, it will be difficult for the moderator to draw attention in the same screen from many participants while playing the game. Simplifying the game while preserving its core mechanism would enhance stakeholder engagement. Ensuring that the game can be easily grasped quickly is crucial, given the limited meeting time often faced during concise meetings. A simplified version could offer a glimpse of the experience and concepts, making it more practical for certain situations. However, the original version remains highly valuable and is recommended for comprehensive 1-hour gameplay.

Risk Assessment and Insight Generation

Weighing risks and rewards for each scenario with the PBB game is recommended not just to improve the game's reality but also to generate valuable insights about diverse perceptions on the risk assessment and the complexities of airside operations. In this case, the RSG can only use the Flow board (Figure 6.1a, pg. 76) to share all possible scenarios, risks, rewards, and the reasonings behind. In addition, combining with thorough data analysis with an iterative development would add more values on remaining relevant, engaging, and aligned with the evolving needs of airside operations. Thus, through the risk assessment, RSG needs to navigate the efficiency trade-off posed by increased automation and focus on strategies to mitigate worst-case scenarios for optimal operations.

Expansion to other domains

The fundamental mechanism of the PBB game (Appendix F) can be adapted for other projects. By mapping out plausible real-life scenarios and chances, this approach can create engaging games for various stakeholders in different operational contexts.

Act on the vision of the Roadmap

The roadmap outlines actionable steps for RSG's future initiatives. First, **new types of communication tools** need to be developed **by Identifying and validating transformative technologies**. In particular, task 6 (giving a signs to flight crews) remains an improvement to realize remote control scenario. In this regard, integrating a real-time monitoring system for prompt AS issue reporting will be vital for realizing remote operations and reducing time lag. VR/AR or drones can also be explored. Moreover, for seamless communications, developing conversational AI for voice control, can be useful, especially when operators need hands-free interaction in operations.

Furthermore, RSG is recommended to develop **new safety measures for hybrid collaboration** with ASs, along with **timely implementation and hiring plans**. Collaboration with stakeholders like ground handlers, airlines, and government will be crucial for consensus on the safety measures, particularly for remote control. Simultaneously, RSG should strategically plan the number of ASs and human workers while sustaining skilled operators. Balancing AS deployment to prevent maintenance bottlenecks and improving operator working conditions are vital to ensure sustainable job retention. Given the labor shortage, it is expected that increasing interaction moments during operations and enhancing motivational communication can further support the workforce.

9. Conclusions

The research explored how a task delegation guideline can help to strike a balance between the decision-making authority retained by humans and that can be transferred to ASs within the context of different levels of autonomy, focusing on the Passenger Boarding Bridge (PBB) at Schiphol Amsterdam Airport.

The study delved into seven influential factors affecting task delegation in HRC and identified 12 themes across four dimensions to guide this process, looking into tensions of perspectives between operators and decision-makers. Notably, high-precision tasks were found suitable for automated systems due to their expertise and speed, while tasks involving communication and inspection were better managed by humans.

The research outcomes highlight two controversial values relevant to task delegation: 1) the significance of reliability in ensuring a comprehensive perspective and 2) efficiency through accuracy, with distinct viewpoints between decision-makers and operators.

A physical board game-style speculative probe, proposed as PBB, illuminated the interplay between these contrasting values and viewpoints, offering organizations the opportunity to simulate possible future scenarios engagingly. By considering trade-offs between risks and rewards, organizations can navigate the equilibrium between tasks suitable for ASs and those better suited for humans.

As a synthesized output of this study, the roadmap provides RSG a conceptual guideline with actionable plans to achieve an optimal hybrid automation scenario, including virtual remote supervision, in the near future.

Therefore, two main outputs of this study, the speculative game and the roadmap from the research, are expected to empower organizations with holistic insights into the evolving dynamics between humans and ASs tasks in task delegation, enhancing both reliability and efficiency in airside operations.

References

Aaltonen, I., Salmi, T., & Marstio, I. (2018a). Refining levels of collaboration to support the design and evaluation of human-robot interaction in the manufacturing industry. Procedia CIRP, 72, 93–98. https://doi.org/10.1016/j.procir.2018.03.214

Aaltonen, I., Salmi, T., & Marstio, I. (2018b). Refining levels of collaboration to support the design and evaluation of human-robot interaction in the manufacturing industry. Procedia CIRP, 72, 93–98. https://doi.org/10.1016/j.procir.2018.03.214

Accelerating Innovation. (n.d.). TU Delft. Retrieved June 20, 2023, from https://www.tudelft.nl/io/onderzoek/mobility/accelerating-innovation

Beer, J. M., Fisk, A. D., & Rogers, W. A. (2014). Toward a Framework for Levels of Robot Autonomy in Human-Robot Interaction. Journal of Human-Robot Interaction, 3(2), 74. https://doi.org/10.5898/JHRI.3.2.Beer

Bertrandias, L., Lowe, B., Sadik-Rozsnyai, O., & Carricano, M. (2021). Delegating decision-making to autonomous products: A value model emphasizing the role of well-being. Technological Forecasting and Social Change, 169, 120846. https://doi.org/10.1016/j.techfore.2021.120846

Bouzekri, E., Canny, A., Martinie, C., Palanque, P., & Gris, C. (2019). Using Task Descriptions with Explicit Representation of Allocation of Functions, Authority and Responsibility to Design and Assess Automation. In B. R. Barricelli, V. Roto, T. Clemmensen, P. Campos, A. Lopes, F. Gonçalves, & J. Abdelnour-Nocera (Eds.), Human Work Interaction Design. Designing Engaging Automation (Vol. 544, pp. 36–56). Springer International Publishing. https://doi.org/10.1007/978-3-030-05297-3_3

Bradshaw, J. M., Feltovich, P. J., & Johnson, M. (2017). Human–Agent Interaction. In G. A. Boy (Ed.), The Handbook of Human-Machine Interaction (1st ed., pp. 283–300). CRC Press. https://doi.org/10.1201/9781315557380-14

Bradshaw, J. M., Hoffman, R. R., Johnson, M., & Woods, D. D. (2013). The Seven Deadly Myths of "Autonomous Systems." IEEE Intelligent Systems, 28(3), 54–61. https://doi.org/10.1109/MIS.2013.70

Brandt, E. (2006). Designing exploratory design games: A framework for participation in Participatory Design? Proceedings of the Ninth Conference on Participatory Design: Expanding Boundaries in Design - Volume 1, 57–66. https://doi.org/10.1145/1147261.1147271

Braun, V., & Clarke, V. (2013). Successful qualitative research: A practical guide for beginners. SAGE.

Bruno, G., & Antonelli, D. (2018). Dynamic task classification and assignment for the management of human-robot collaborative teams in workcells. The International Journal of Advanced Manufacturing Technology, 98(9–12), 2415–2427. https://doi.org/10.1007/s00170-018-2400-4

Castelfranchi, C., & Falcone, R. (1998). Towards a theory of delegation for agent-based systems. Robotics and Autonomous Systems, 24(3–4), 141–157. https://doi.org/10.1016/S0921-8890(98)00028-1

Cila, N. (2022). Designing Human-Agent Collaborations: Commitment, responsiveness, and support. CHI Conference on Human Factors in Computing Systems, 1–18. https://doi.org/10.1145/3491102.3517500

Clarke, V., & Braun, V. (2014). Thematic Analysis. In T. Teo (Ed.), Encyclopedia of Critical Psychology (pp. 1947–1952). Springer New York. https://doi.org/10.1007/978-1-4614-5583-7_311

Csiszár, C. (2016). Airport Smartness Index – evaluation method of airport information services.

Dearden, A., Harrison, M., & Wright, P. (2000). Allocation of function: Scenarios, context and the economics of effort. International Journal of Human-Computer Studies, 52(2), 289–318. https://doi.org/10.1006/ijhc.1999.0290

Desai, M., Stubbs, K., Steinfeld, A., & Yanco, H. (2009). Creating Trustworthy Robots: Lessons and Inspirations from Automated Systems.

Engelberger, J. F. (1983). Robotics in Practice. Springer US. https://doi.org/10.1007/978-1-4684-7120-5

Floridi, L., Cowls, J., Beltrametti, M., Chatila, R., Chazerand, P., Dignum, V., Luetge, C., Madelin, R., Pagallo, U., Rossi, F., Schafer, B., Valcke, P., & Vayena, E. (2018). AI4People—An Ethical Framework for a Good AI Society: Opportunities, Risks, Principles, and Recommendations. Minds and Machines, 28(4), 689–707. https://doi.org/10.1007/s11023-018-9482-5

Gil, M., Albert, M., Fons, J., & Pelechano, V. (2020). Engineering human-in-the-loop interactions in cyber-physical systems. Information and Software Technology, 126, 106349. https://doi.org/10.1016/j.infsof.2020.106349

Grahn, S., Gopinath, V., Wang, X. V., & Johansen, K. (2018). Exploring a Model for Production System Design to Utilize Large Robots in Human-Robot Collaborative Assembly Cells. Procedia Manufacturing, 25, 612–619. https://doi.org/10.1016/j.promfg.2018.06.094

Groover, M. P. (2023, March 2). automation. Encyclopedia Britannica. https://www.britannica.com/technology/automation

Hopko, S., Wang, J., & Mehta, R. (2022). Human Factors Considerations and Metrics in Shared Space Human-Robot Collaboration: A Systematic Review. Frontiers in Robotics and AI, 9, 799522. https://doi.org/10.3389/frobt.2022.799522

ISO 8373:2021(en), Robotics—Vocabulary. (n.d.). Retrieved March 10, 2023, from https://www.iso.org/obp/ui/#iso:std:iso:8373:ed-3:v1:en:term:3.4

Janssen, C. P., Donker, S. F., Brumby, D. P., & Kun, A. L. (2019). History and future of human-automation interaction. International Journal of Human-Computer Studies, 131, 99–107. https://doi.org/10.1016/j.ijhcs.2019.05.006

Kopp, T., Baumgartner, M., & Kinkel, S. (2021). Success factors for introducing industrial human-robot interaction in practice: An empirically driven framework. The International Journal of Advanced Manufacturing Technology, 112(3–4), 685–704. https://doi.org/10.1007/s00170-020-06398-0

Krüger, J., Lien, T. K., & Verl, A. (2009). Cooperation of human and machines in assembly lines. CIRP Annals, 58(2), 628–646. https://doi.org/10.1016/j.cirp.2009.09.009

Lakhmani, S. G., Wright, J. L., & Chen, J. Y. C. (2020). Transparent interaction and human–robot collaboration for military operations. In Living with Robots (pp. 1–19). Elsevier. https://doi.org/10.1016/B978-0-12-815367-3.00001-3

Landen, D. (2011). Complex Task Allocation for Delegation: From Theory to Practice.

Lasiewicz-Sych, A. (2019). TRADE-OFF GAMES AND METHODS IN PARTICIPATORY DESIGN. Space&FORM, 2019(39), 57–80. https://doi.org/10.21005/pif.2019.39.B-03

Liu, C., Susilo, Y. O., & Karlström, A. (2015). The influence of weather characteristics variability on individual's travel mode choice in different seasons and regions in Sweden. Transport Policy, 41, 147–158. https://doi.org/10.1016/j.tranpol.2015.01.001

Liu, F., & Zuo, M. (2011). HUMAN-MACHINE FUNCTION ALLOCATION IN INFORMATION SYSTEMS: A COMPREHENSIVE APPROACH.

Locke, E. (2000). Motivation, Cognition, and Action: An Analysis of Studies of Task Goals and Knowledge. Applied Psychology, 49(3), 408–429. https://doi.org/10.1111/1464-0597.00023

Lubars, B., & Tan, C. (2019). Ask not what AI can do, but what AI should do: Towards a framework of task delegability.

MacQueen, K. M., McLellan, E., Kay, K., & Milstein, B. (2008). Codebook Development for Team-Based Qualitative Analysis. CAM Journal, 10(2), 31–36. https://doi.org/10.1177/1525822X980100020301

Moravec, H. P. (2022, November 5). Robot | Definition, History, Uses, Types, & Facts | Britannica. https://www.britannica.com/technology/robot-technology

Nof, S. Y. (Ed.). (2009). Springer Handbook of Automation. Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-540-78831-7

Onnasch, L., & Roesler, E. (2021). A Taxonomy to Structure and Analyze Human–Robot Interaction. International Journal of Social Robotics, 13(4), 833–849. https://doi.org/10.1007/s12369-020-00666-5

Ore, F., Hansson, L., & Wiktorsson, M. (2017). Method for Design of Human-industrial Robot Collaboration Workstations. Procedia Manufacturing, 11, 4–12. https://doi.org/10.1016/j.promfg.2017.07.112

Parker, C., Scott, S., & Geddes, A. (2019). Snowball Sampling. SAGE Research Methods Foundations. http://methods.sagepub.com/foundations/snowball-sampling

Parker, S. K., & Grote, G. (2022). Automation, Algorithms, and Beyond: Why Work Design Matters More Than Ever in a Digital World. Applied Psychology, 71(4), 1171–1204. https://doi.org/10.1111/apps.12241

Saadati, P., Abdelnour-Nocera, J., & Clemmensen, T. (2022). Co-designing Prototypes for User Experience and Engagement in Automation: Case Study of London-based Airport Future Workplace. In G. Bhutkar, B. R. Barricelli, Q. Xiangang, T. Clemmensen, F. Gonçalves, J. Abdelnour-Nocera, A. Lopes, F. Lyu, R. Zhou, & W. Hou (Eds.), Human Work Interaction Design. Artificial Intelligence and Designing for a Positive Work Experience in a Low Desire Society (Vol. 609, pp. 158–177). Springer International Publishing. https://doi.org/10.1007/978-3-031-02904-2_8

Saldaña, Johnny. (2009). The coding manual for qualitative researchers (1–1 online resource (x, 223 pages) : illustrations). Sage; WorldCat.org.

Schiphol | Een autonome luchthaven in 2050. (2020, May 1). Schiphol. https://www.schiphol.nl/nl/innovatie/blog/een-autonome-luchthaven-in-2050/

Siriaraya, P., Visch, V., Vermeeren, A., & Bas, M. (2018). A cookbook method for Persuasive Game Design. International Journal of Serious Games, 5(1). https://doi.org/10.17083/ijsg.v5i1.159

Sjögren, P. E., Dan. (1991). From System Descriptions to Scripts for Action. In Design at Work. CRC Press.

Smith, J. E. (2020). Smart machines and service work: Automation in an age of stagnation. Reaktion Books, Ltd.

Stickdorn, M., & Schneider, J. (Eds.). (2021). This is service design thinking: Basics, tools, cases (Paperback edition, 9th printing). BIS Publishers.

Tan, E. (2014). Negotiation and Design for the Self-Organizing City.

Team, A. L. (2020, June 25). A Guide to Airport Ramp Operations, Ground Handling & Ground Support Equipment (GSE). Aviation Learnings. https://aviationlearnings.com/ground-handling-ramp-operations-aircraft-ground-support-equipment-gse-machines-that-supplement-the-airplane/

Ulfert, A.-S., Antoni, C. H., & Ellwart, T. (2022). The role of agent autonomy in using decision support systems at work. Computers in Human Behavior, 126, 106987. https://doi.org/10.1016/j.chb.2021.106987

Visch, V., Vegt, N., & Anderiesen, H. (2013). Persuasive Game Design: A model and its definitions.

Welge, J., & Hassenzahl, M. (2016). Better Than Human: About the Psychological Superpowers of Robots. In A. Agah, J.-J. Cabibihan, A. M. Howard, M. A. Salichs, & H. He (Eds.), Social Robotics (Vol. 9979, pp. 993–1002). Springer International Publishing. https://doi.org/10.1007/978-3-319-47437-3_97

Wilhelm, B., Manfred, B., Braun, M., Rally, P., & Scholtz, O. (2016). Lightweight robots in manual assembly – best to start simply! Examining companies' initial experiences with lightweight robots.

Appendices

A. Expert Interviews: Protocols

Purpose: To understand current automatic PBB operation issues

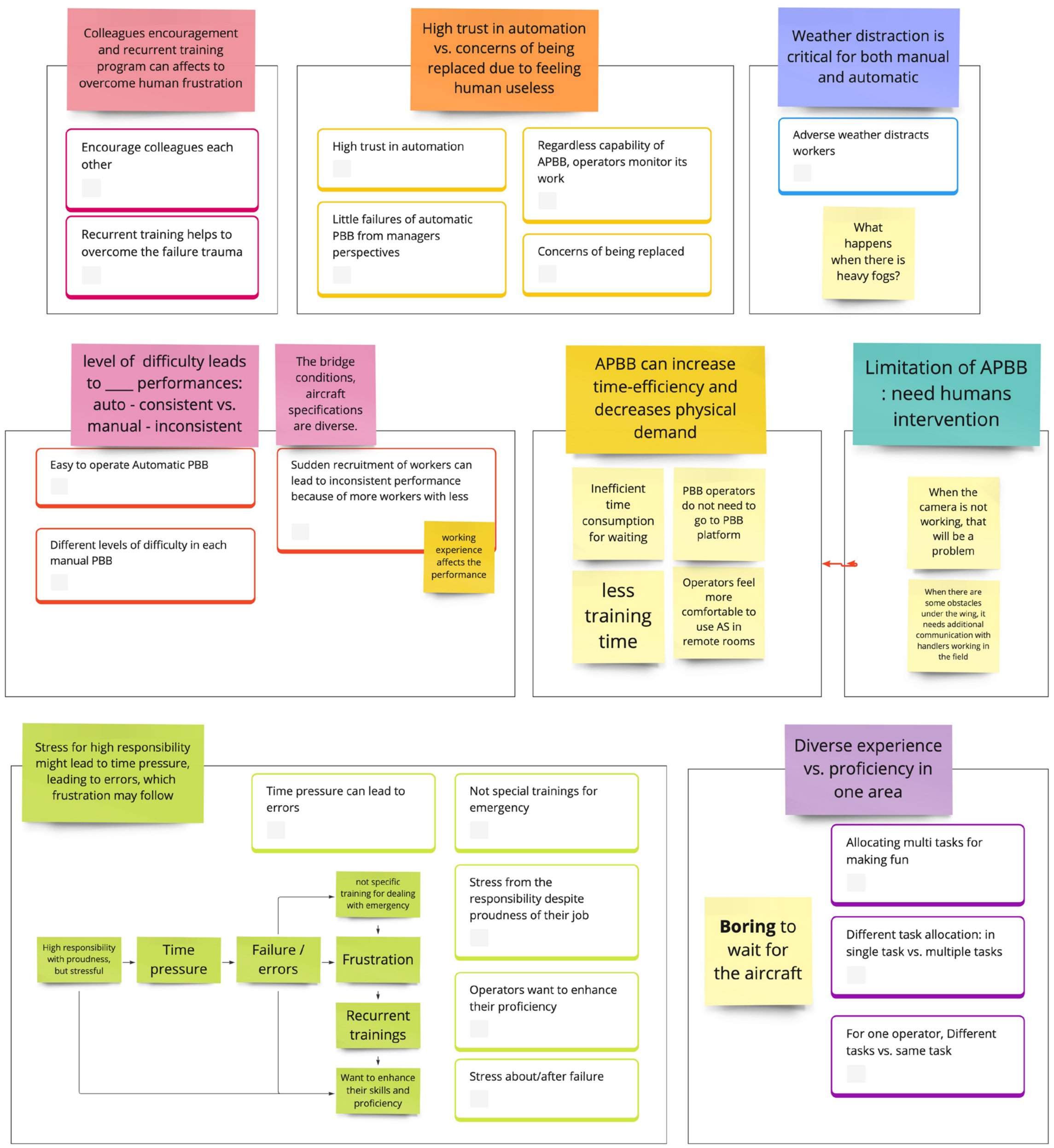
Expected time: 30 mins

1. Can you tell me about yourself?
2. Have you experienced both Automatic PBB and manual? Please tell me about your experience (positive? Or negative?).
    - Could you tell me what the operators do?
    - Do you know how the automatic PBB works? (i.e. which part is automated technically)
    - Do you have any other concerns?
    - How do you explain these systems to new colleagues? Do they get training for these?
    - if yes, what do they learn? Are they satisfied with their training?
3. I read an internal document that the failure rate of Full Automatic Connection was (still) relatively high compared with the expected performance. Could you explain more about why?
4. In manual operation, there are still failures.
    - Why do they happen?
    - What kinds of failures happened in the past (first-hand/second-hand)?
    - When(in which circumstances) do they happen?
    - How it was solved? (How do they solve them? Are there any protocols? Do they ask for help? If yes, from whom and what is the nature of their work?)
    - [if the answer is insufficient] Is it because of the adverse weather, time pressure, any other distractions, time of day, aircraft type, and so on?
5. Have you heard about any issues from operators?

[if the answer is insufficient] about stress, the working environment, and so on.

[Open-ended questions] Do you have any other comments? Would it be okay for me to contact you again if needed?

B. Expert Interviews: Results



C. In-depth interview: Protocols

For operators (with APBB experience)

1. How is your experience different in operating MPBB and APBB? (was it positive/ negative? and why?)

2-1. If some errors occurred, what are they when comparing the two types?

2-2. Why do they occur? Were they technical issues mainly? or human mistakes?

2-3. How do you solve them? and How long does it take to solve it?

3. Who takes control for these subtasks(sense,plan,action) in MPBB and APBB? and why?

4. What if all the APBB is controlled in a remote control room, how would it be different? and how would you take control of these subtasks?

For operators (without APBB experience)

1. How is your experience in operating MPBB? (was it positive/negative? and why?)

2-1. If some errors occurred, what are they when comparing the two types?

2-2. Why do they occur? Were they technical issues mainly? or human mistakes?

2-3. How do you solve them? and How long does it take to solve it?

3. Who takes control for these subtasks(sense,plan,action) in MPBB, how would it be in APBB? and why?

4. What if all the APBB is controlled in a remote control room, how would it be different? and how would you take control of these subtasks?

For decision-makers who may influence implementing and developing ASs into practice

1. How would the operations be different in MPBB and APBB, if you asked someone to complete the given (above) task? - while clarifying the flow of Figure 4.2

2-1. If some errors occurred, what would they be when comparing the two types?

2-2. Why would they occur? Were they technical issues mainly? or human mistakes?

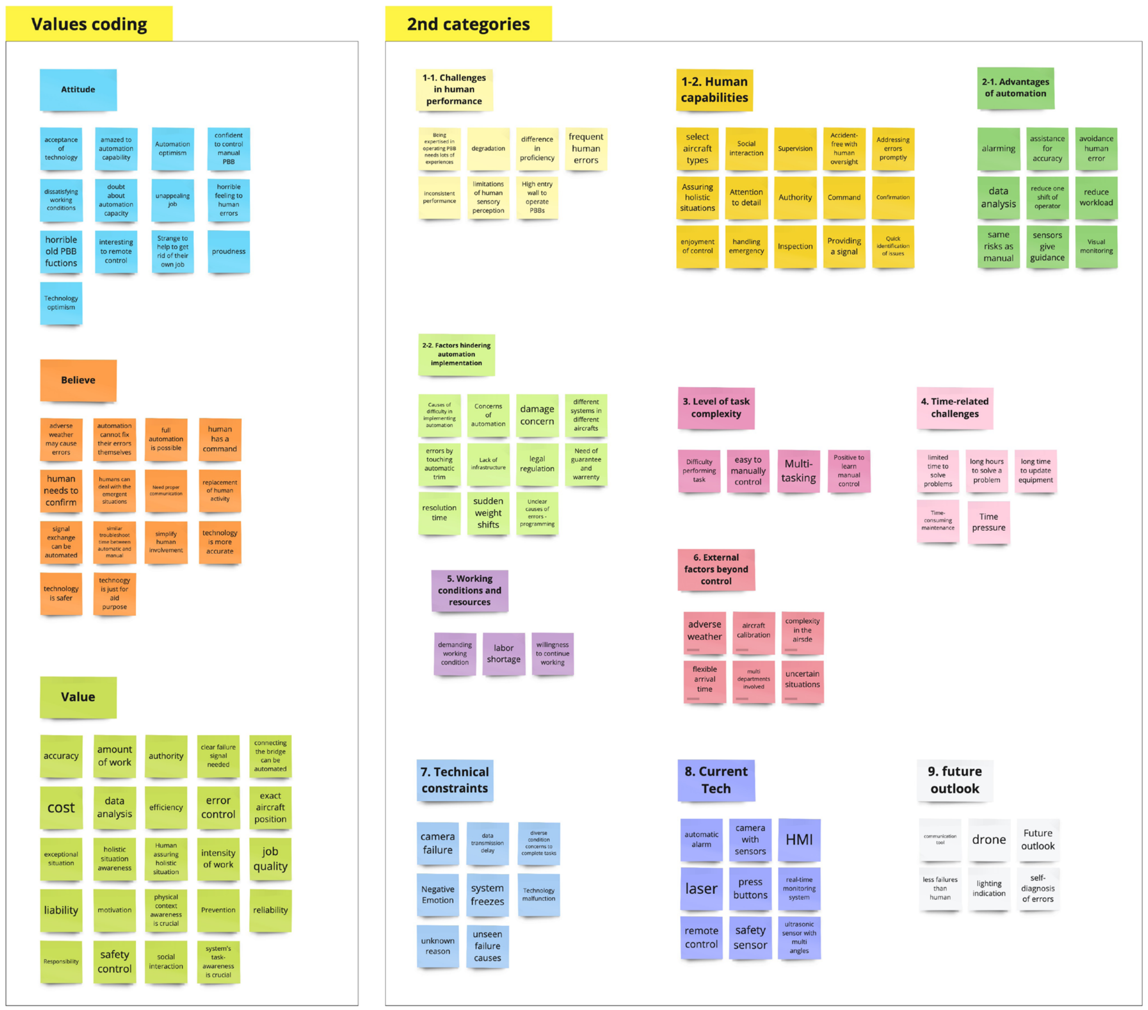
2-3. How would you solve them? and How long would it take to solve it?

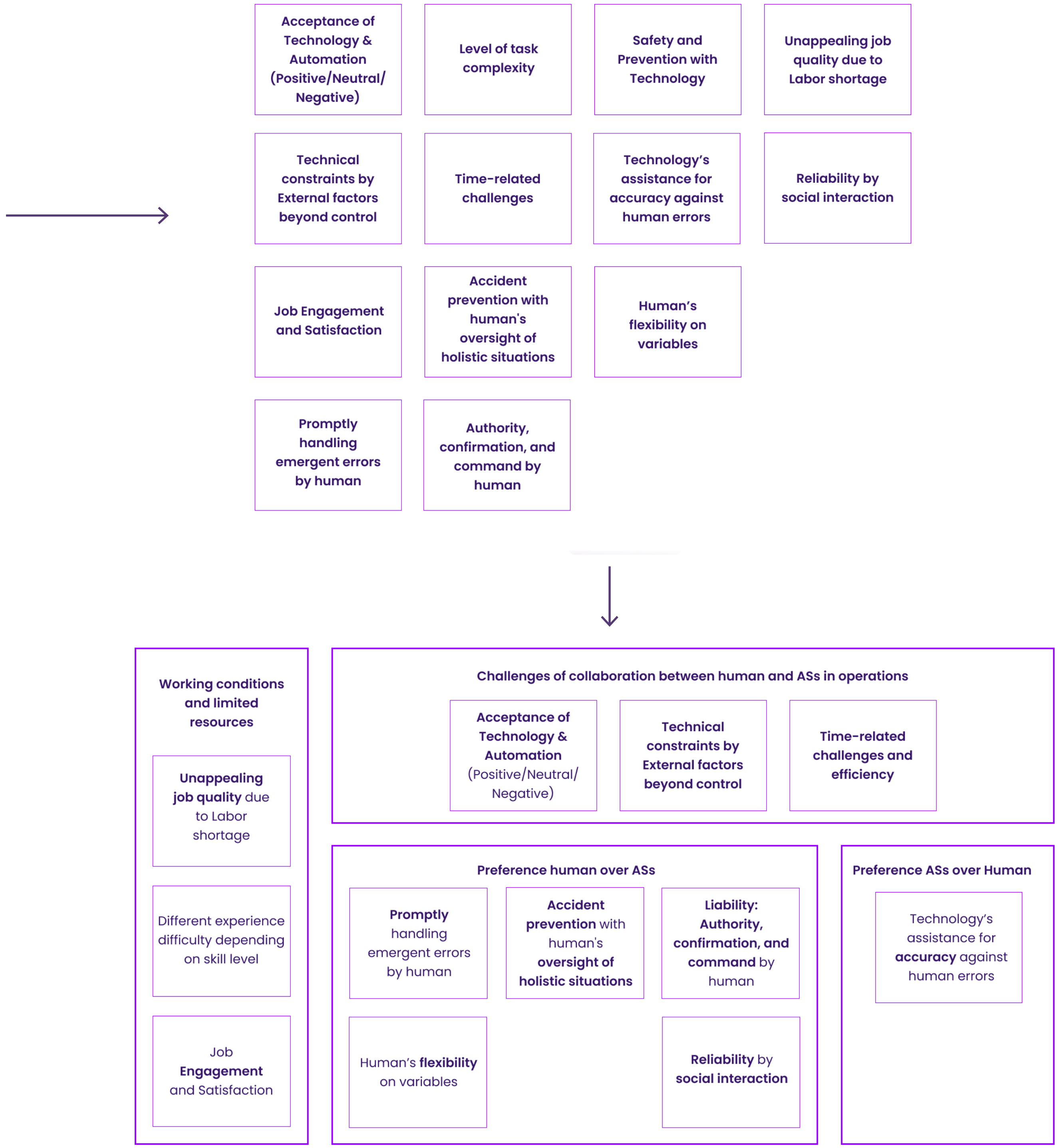
3. If you were to ask someone to complete the given task, who would take the control of these subtasks (sense,plan,action) in MPBB and APBB?, and why?

4. What if all the APBB is controlled in a remote control room, how would it be different? and how would you let the operator take control of these subtasks?

D. In-depth interview - Results

1. Reflexive Thematic Analysis (RTA)

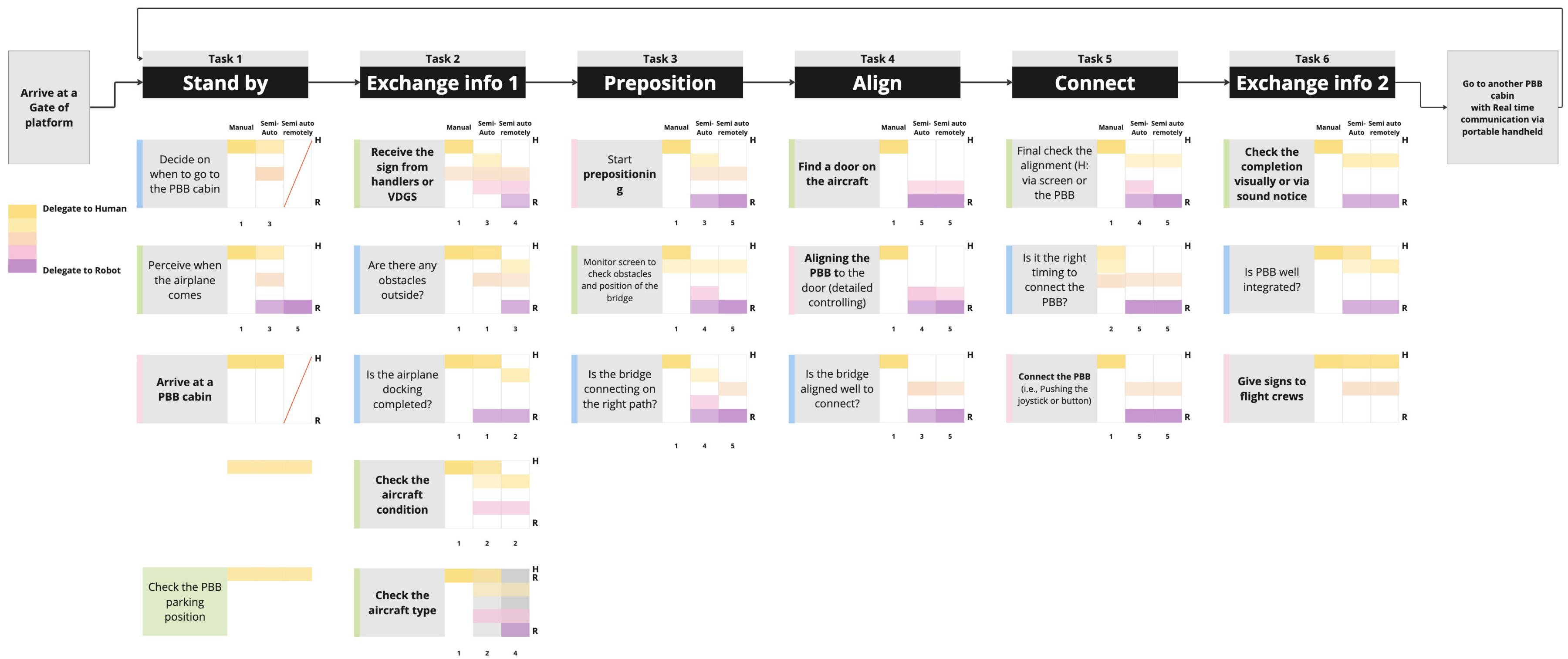




2. Task delegability

DM

O



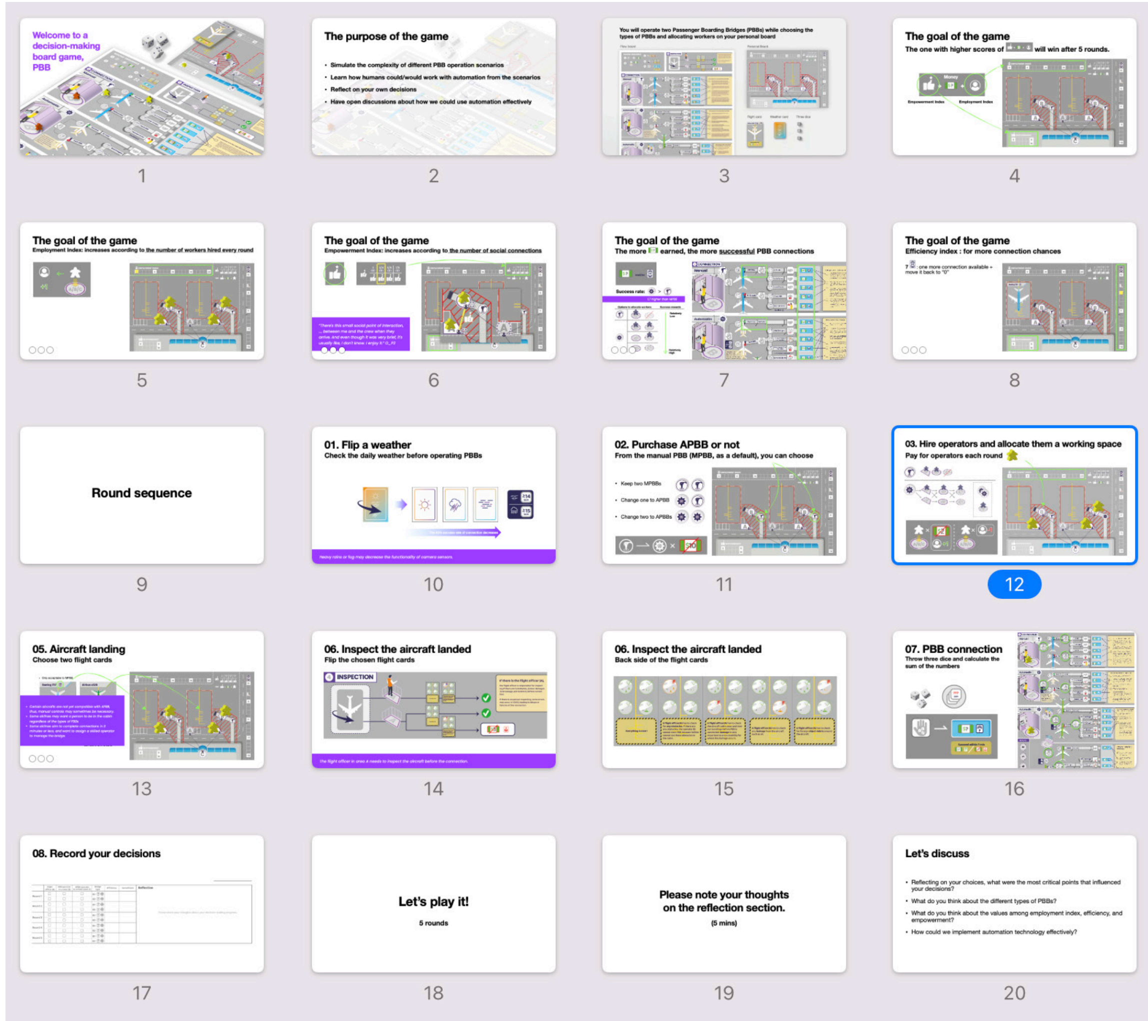
E. Survey: Questionnaires

Survey	Tasks will be 6 steps in PBB operation task flow. So particiapants will be asked 6 times with the same formate of these statements. A set of questions for each task will take 2-3 mins	(Lubars & Tan, 2019)	10-13
Purpose	To discover correlations between human preferences and task delegation To find the spot of tensions in perspectives towards ASs of APBB between operators and managers regarding task delegation To discover how much levels that operators/managers would prefer in each task delegation		
Participants	Operators who have experience in operating both PBB and APBB (min. 10)		
	Managers who have knowledge about operations in PBB and APBB (i.e., asset managers, asset suppliers, etc.) (min.10)		
Duration	10 mins		
Tools	- Google survey explaining 6 steps of tasks with explanation (in Dutch/English)		
Two survey versions will be created.			
For operators	The survey inlcudes **all the four factors** ask participants “If you were to do the given (above) task, what level of AI/machine assistance would you prefer?”		
For managers or experts	The survey includes only **difficulty, risk, and trust**, and ask participants “If you were to ask someone to complete the given (above) task, what level of AI/machine assistance would you prefer?”		
Research info	Brief research purpose, consent form		
Personal Info	How would you rate your level of computer proficiency?	Far above average / Slightly above average / Average / Slightly below average / Far below average / Prefer not to say	
Flow of the task descriptions			
Task by task	**For each of the following statements, please indicate the extent to which you agree or disagree for the above task in operating Automatic Passenger Boarding Bridge: (five-point Likert scale)**		
Difficulty	*1. This task requires social skills to complete.*		
Difficulty	*2. This task requires creativity to complete.*		
Difficulty	*3. This task requires a great deal of time or effort to complete.*		
	4. Attention check, please choose ’Strongly Agree’ for this one.		
Difficulty	*5. It takes significant training or expertise to be qualified for this task.*		
Difficulty	*6. I am confident in my own abilities to complete this task.*		
Risk	*7. In the case of mistakes or failure on this task, someone needs to be held accountable.*		
Risk	*8. A complex or unpredictable environment/situation is likely to cause this task to fail.*		
Risk	*9. Failure would result in a substantial negative impact on my life or the lives of others.*		
Motivation	*10. I would feel motivated to perform this task, even without needing to; for example, it is fun, interesting, or meaningful to me.*	only for operators	
Motivation	*11. I am interested in learning how to master this task, not just in completing the task.*	only for operators	
Motivation	*12. I consider this task especially valuable or important; I would feel committed to completing this task because of the value it adds to my life or the lives of others.*	only for operators	
	13. Attention check, please choose ’Strongly Disagree’ for this one.		
Trust	*14. I trust the AI agent’s ability to reliably complete the task.*		
Trust	*15. Understanding the reasons behind the AI agent’s actions is important for me to trust the AI agent on this task (e.g., explanations are necessary).*		
Trust	*16. I trust the AI agent’s actions to protect my interests and align with my values for this task.*		
degree of delegatibility	**For operators: if you were to do the given (above) task, what level of AI/machine assistance would you prefer? For managers: If you were to ask someone to complete the given (above) task, what level of AI/machine assistance would you prefer?**		
	1. Full AI automation: decisions and actions are made automatically by the AI once the task is assigned; you do nothing.		
	2. The AI leads and the human assists: the AI performs the task, but asks you for suggestions/confirmation when appropriate.		
	3. The human leads and the AI assists: you do the task mostly on your own, but the AI offers recommendations or help when appropriate (e.g., you get stuck or AI sees possible mistakes).		
	4. No AI assistance: you do the task completely on your own.		

F. Progress of designing the board game mechanism

		possibilities						Gold	Efficiency	Last sum
Manual PBB	w B	Success	75%	Success in 1 min	21.50%			5	1	13,14,15
		sum >=9		Success between 1-3 min	75.00%			5		sum =< 12
				Success longer than 3 min	3.50%			5	-1	16,17,18
	sum =<8	Connect ERR	25.00%	human error (collision)	50%			-2	-1	even
				Sensor failures (collision)	50%			-1	-2	odd
Automatic PBB	w B	Success in 1 min	85.00%					5	2	sum >=8
1) rainy - sum>=15 2) fog - sum>=14	sum =<7	Tech errors (switch to manual / stop)	15.00%	Bad images caused by illumination effection	16.2%			3	0	sum>=14
				Accurate of vision system	21.3%			2	-2	12,13
				Wrong stop position / wrong aircraft type from VDGS	37.5%			3	-1	sum <=9
				PBB sensor failures	25.0%			3	-2	10,11
		sum >=8								
	w/o B + w/ C	Success in 1 min	85.00%					5	3	
		Tech errors (switch to manual / stop / crash)	15.00%	Bad images caused by illumination effection	16.2%			3	-1	sum>=14
				Accurate of vision system	21.3%			2	-3	12,13
				Wrong stop position / wrong aircraft type from VDGS	37.5%			3	-2	sum <=9
				PBB sensor failures	25.0%			3	-3	10,11
	W/o B + w/o C	Success in 1 min	85.00%					5	4	
		Tech errors (switch to manual / stop / crash)	15.00%	Delay	90%	Bad images caused by illumination effection	16.2%	3	-1	sum>=14
		sum =<7		sum>=7		Accurate of vision system	21.3%	2	-3	12,13
						Wrong stop position / wrong aircraft type from VDGS	37.5%	3	-2	sum <=9
				sum=<6		PBB sensor failures	25.0%	3	-3	10,11
				crash and damage to aircraft	10%			-10	-5	

G. Evaluation: protocol materials



H. Informed Consent: Expert Interviews

Informed Consent

Dear Participant,

Thank you for collaborating with this research on the topic: **Framing task delegation for human-automation collaboration.** This study is for a master's thesis and is done by **Jeongha Joo** from the TU Delft and Innovation Hub in the Royal Schiphol Group.

Purpose of the research
This research aims to analyze the collaborative interaction context with automated systems and develop a conceptual guideline to support effective task delegation processes. To collect your perspective, several questions will be asked. The questions will be about your experiences in operating the automatic system. It will take you approximately **60** minutes to complete. You are free to ask any questions to the researcher.

Benefits and risks of participating
In this study, you will be asked to allow the researcher to participate in an in-depth interview. There are no severe risks in these tests. If at any point you feel uncomfortable, the experiment will be stopped. As with any online activity, the risk of a breach is always possible. To the best of our ability, your answers in this study will remain confidential. We will minimize any risks by

- not asking for your name and personal information
- stopping the interviews if you don't feel comfortable.
- explaining the protocols
- answering any questions
- following all covid-19 measures
- anonymizing the collected data, such as videos, photos, voice records, etc.
- removing the data after finalizing the research

Withdrawal from the study
Participation in this study is entirely voluntary, and you can withdraw anytime. You are free to omit any questions. We will pre-process the data in the coming months, and you can ask us to remove your data at any moment within this month based on the participant number in your informed consent.

Anonymize & Store & Access the data
The collected data will be anonymized in such a way that the name & the address of the participants can no longer be identified. All audio recordings will be stored securely and destroyed after transcription. Also, all the photos and videos will be anonymously reprocessed.
In the publication only the following results will be published:

- The statistical results of any subjective questions
- The anonymized images and/or videos
- Quotes with anonymized participant numbers

PLEASE TICK THE APPROPRIATE BOXES	Yes	No
A: GENERAL AGREEMENT – RESEARCH GOALS, PARTICPANT TASKS AND VOLUNTARY PARTICIPATION		

PLEASE TICK THE APPROPRIATE BOXES	Yes	No
1. I have read and understood the study information dated [__/__/2023], 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.	☐	☐
3. I understand that taking part in the study involves:	☐	☐
• *Transcripts in the interview* • *an audio-recorded interview*		
4. I understand that I will be compensated for my participation by	☐	☐
☐ *Volunteering* ☐ *VVV voucher (20 euros/hr)* • *Please leave your email below to receive the voucher which we will send to you later.* *Email:____________________________*		
5. I understand that the study will end in 30 minutes.	☐	☐
B: POTENTIAL RISKS OF PARTICIPATING (INCLUDING DATA PROTECTION)		
6. I understand that taking part in the study involves the following risks [a]. I understand that these will be mitigated by [b]	☐	☐
[a] • *No risks* *[b]* • *The participants will have the ability to ask for the interview to stop at any point.* • *clear guidelines and procedures will be informed to participants.*		
9. I understand that the following steps will be taken to minimize the threat of a data breach and protect my identity in the event of such a breach	☐	☐
That the data will be anonymized with limited access. The voice will not be used, and only quotes from transcription will be taken with an anonymized participant number. All the images that participants are exposed will be blurred. After the final presentation, all the data will be deleted.		
C: RESEARCH PUBLICATION, DISSEMINATION AND APPLICATION		
12. I understand that after the research study the de-identified information I provide will be used for	☐	☐
• *The statistical results of any subjective questions* • *Reprocessed images or drawings of the environment in the thesis report and final presentation*		
13. I agree that my responses, views or other input can be quoted anonymously in research outputs	☐	☐

PLEASE TICK THE APPROPRIATE BOXES	Yes	No
D: (LONGTERM) DATA STORAGE, ACCESS AND REUSE		
14. I give permission for the de-identified questionnaires and corpus that I provide to be archived in the OneDrive with limited access to corresponding and responsible researchers so it can be used for future research and learning.	☐	☐
15. The data will NOT be shared and re-used by default. The default choice of this question is NO	☐	☒

Signatures

Name of participant [printed] Signature Date

[Add legal representative, and/or amend text for assent where participants cannot give consent as applicable]

I, as legal representative, have witnessed the accurate reading of the consent form with the potential participant and the individual has had the opportunity to ask questions. I confirm that the individual has given consent freely.

Name of witness [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.

Jeongha Joo
Himanshu Verma
Eui Young Kim
Garoa Gomez Beldarraiin

Researcher name [printed] Signature Date

Study contact details for further information:

Jeongha Joo, Master's student (TU Delft)
j.joo@student.tudelft.nl

Himanshu Verma, Ph.D. Assistant Professor
Faculty of Industrial Design Engineering, Delft University of Technology (TU Delft)
H.Verma@tudelft.nl

Eui Young Kim, Ph.D. Assistant Professor
Faculty of Industrial Design Engineering, Delft University of Technology (TU Delft)
E.Kim@tudelft.nl

Garoa Gomez Beldarrain, Ph.D Student (TU Delft)
G.GomezBeldarrain@tudelft.nl

I. Consent Form: In-depth Interviews

Informed Consent

Dear Participant,

Thank you for collaborating with this research on the topic: **Framing task delegation for human-automation collaboration.** This study is for a master's thesis and is done by **Jeongha Joo** from the TU Delft and Innovation Hub in the Royal Schiphol Group.

Purpose of the research
The objective of this study is to assess a speculative game design that aids organizations in optimizing their task delegation processes. To gather your valuable insights, a post-discussion session will be conducted after playing the game. Playing the game and the post-discussion is expected to take around **60-80** minutes in total, and you are welcome to ask any questions or seek clarifications from the researcher.

Benefits and risks of participating
In this study, you will be asked to allow the researcher to participate in a workshop. There are no severe risks in these tests. If at any point you feel uncomfortable, the experiment will be stopped. To the best of our ability, your answers in this study will remain confidential. We will minimize any risks by

- not asking for your name and personal information
- stopping the interviews if you don't feel comfortable.
- explaining the protocols
- answering any questions
- following all covid-19 measures
- anonymizing the collected data, such as videos, photos, voice records, etc.
- removing the data after finalizing the research

Withdrawal from the study
Participation in this study is entirely voluntary, and you can withdraw anytime. You are free to omit any questions. We will pre-process the data in the coming months, and you can ask us to remove your data at any moment within this month based on the participant number in your informed consent.

Anonymize & Store & Access the data
The collected data will be anonymized in such a way that the name & the address of the participants can no longer be identified. All audio recordings will be stored securely and destroyed after transcription. Also, all the photos and videos will be anonymously reprocessed.
In the publication only the following results will be published:

- The anonymized images and/or videos
- Quotes with anonymized participant numbers

PLEASE TICK THE APPROPRIATE BOXES	Yes	No
A: GENERAL AGREEMENT – RESEARCH GOALS, PARTICPANT TASKS AND VOLUNTARY PARTICIPATION		

PLEASE TICK THE APPROPRIATE BOXES	Yes	No
1. I have read and understood the study information dated [__/__/2023], 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.	☐	☐
3. I understand that taking part in the study involves:	☐	☐
• *Transcripts in the workshop* • *an audio-recorded workshop* • *Photos during workshop*		
4. I understand that I will be compensated for my participation by	☐	☐
☐ *Volunteering* • *Please leave your email below to receive the voucher which we will send to you later.* *Email:*______________________		
5. I understand that the study will end in 60-80 minutes.	☐	☐
B: POTENTIAL RISKS OF PARTICIPATING (INCLUDING DATA PROTECTION)		
6. I understand that taking part in the study involves the following risks [a]. I understand that these will be mitigated by [b]	☐	☐
[a] • *No risks* *[b]* • *The participants will have the ability to ask for the workshop to stop at any point.* • *clear guidelines and procedures will be informed to participants.*		
9. I understand that the following steps will be taken to minimize the threat of a data breach and protect my identity in the event of such a breach	☐	☐
That the data will be anonymized with limited access. The voice will not be used, and only quotes from transcription will be taken with an anonymized participant number. All the images that participants are exposed will be blurred. After the final presentation, all the data will be deleted.		
C: RESEARCH PUBLICATION, DISSEMINATION AND APPLICATION		
12. I understand that after the research study the de-identified information I provide will be used for	☐	☐
• *The statistical results of any subjective questions* • *Reprocessed images or drawings of the environment in the thesis report and final presentation*		
13. I agree that my responses, views or other input can be quoted anonymously in research outputs	☐	☐
PLEASE TICK THE APPROPRIATE BOXES	**Yes**	**No**
D: (LONGTERM) DATA STORAGE, ACCESS AND REUSE		
14. I give permission for the de-identified questionnaires and corpus that I provide to be archived in the OneDrive with limited access to corresponding and responsible researchers so it can be used for future research and learning.	☐	☐
15. The data will NOT be shared and re-used by default. The default choice of this question is NO	☐	☒

Signatures

Name of participant [printed]	Signature	Date

[Add legal representative, and/or amend text for assent where participants cannot give consent as applicable]

I, as legal representative, have witnessed the accurate reading of the consent form with the potential participant and the individual has had the opportunity to ask questions. I confirm that the individual has given consent freely.

Name of witness [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.

Jeongha Joo
Himanshu Verma
Eui Young Kim
Garoa Gomez Beldarraiin

Researcher name [printed]	Signature	Date

Study contact details for further information:

Jeongha Joo, Master's student (TU Delft)
j.joo@student.tudelft.nl

Himanshu Verma, Ph.D. Assistant Professor
Faculty of Industrial Design Engineering, Delft University of Technology (TU Delft)
H.Verma@tudelft.nl

Eui Young Kim, Ph.D. Assistant Professor
Faculty of Industrial Design Engineering, Delft University of Technology (TU Delft)
E.Kim@tudelft.nl

Garoa Gomez Beldarrain, Ph.D Student (TU Delft)
G.GomezBeldarrain@tudelft.nl

J. Approximate timeframe in transition of different types of PBB in the AAS

(Number of equipment)	Current	1 year	5 years	10 years	15 years	20 years
MPBB	132	123	92	52	12	0
Automatic PBB	1	9	41	81	121	133
Remote control room (assume that 1 panel can perform 4 APBBs)	0	2	10	20	30	33

K. Project Design Brief

DESIGN FOR our future

TUDelft

IDE Master Graduation

Project team, Procedural checks and personal Project brief

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

- The student defines the team, what he/she is going to do/deliver and how that will come about.
- SSC E&SA (Shared Service Center, Education & Student Affairs) reports on the student's registration and study progress.
- IDE's Board of Examiners confirms if the student is allowed to start the Graduation Project.

USE ADOBE ACROBAT READER TO OPEN, EDIT AND SAVE THIS DOCUMENT

Download again and reopen in case you tried other software, such as Preview (Mac) or a webbrowser

STUDENT DATA & MASTER PROGRAMME

Save this form according the format "IDE Master Graduation Project Brief_familyname_firstname_studentnumber_dd-mm-yyyy". Complete all blue parts of the form and include the approved Project Brief in your Graduation Report as Appendix 1 !

family name: Jeongha

initials: J given name: Joo

student number: [redacted]

street & no.: [redacted]

zipcode & city: [redacted]

country: [redacted]

phone: [redacted]

email: j.joo@student.tudelft.nl

Your master programme (only select the options that apply to you):

IDE master(s): IPD / ★ DfI / SPD

2nd non-IDE master:

individual programme: - - (give date of approval)

honours programme: Honours Programme Master

specialisation / annotation: Medisign / Tech. in Sustainable Design / Entrepeneurship

SUPERVISORY TEAM **

Fill in the required data for the supervisory team members. Please check the instructions on the right !

** chair: Himanshu Verma dept. / section: SDE/KIND

** mentor: Garoa Gomez Bel, Eui Young Kim dept. / section: DOS

2nd mentor: Rosina Kortey

organisation: Royal Schiphol Group

city: Schiphol country: The Netherlands

comments (optional):

Chair should request the IDE Board of Examiners for approval of a non-IDE mentor, including a motivation letter and c.v..

Second mentor only applies in case the assignment is hosted by an external organisation.

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

IDE TU Delft - E&SA Department /// Graduation project brief & study overview /// 2018-01 v30 Page 1 of 7

Procedural Checks - IDE Master Graduation

APPROVAL PROJECT BRIEF
To be filled in by the chair of the supervisory team.

chair Himanshu Verma date - - signature

CHECK STUDY PROGRESS
To be filled in by the SSC E&SA (Shared Service Center, 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 the conditional requirements into account, can be part of the exam programme ______ EC

List of electives obtained before the third semester without approval of the BoE

YES all 1st year master courses passed

NO missing 1st year master courses are:

name ______ date - - signature ______

FORMAL APPROVAL GRADUATION PROJECT
To be filled in by the Board of Examiners of IDE TU Delft. Please check the supervisory team and study the parts of the brief marked **.
Next, please assess, (dis)approve and sign this Project Brief, by using the criteria below.

- Does the project fit within the (MSc)-programme of the student (taking into account, if described, the activities done next to the obligatory MSc specific courses)?
- Is the level of the project challenging enough for a MSc IDE graduating student?
- Is the project expected to be doable within 100 working days/20 weeks ?
- Does the composition of the supervisory team comply with the regulations and fit the assignment ?

Content: APPROVED NOT APPROVED

Procedure: APPROVED NOT APPROVED

comments

name ______ date - - signature ______

Personal Project Brief - IDE Master Graduation

Framing task delegation for human-robot collaboration in automation project title

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

start date 27 - 02 - 2023 02 - 08 - 2023 end date

INTRODUCTION **
Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

[Task delegation in Human-Robots Collaboration]
Automation technology is increasingly integrated into our lives, including AI and machine learning. Some believe full automation will cause "technological unemployment" and "dystopia of mechanization," but instead of replacing humans, it's reconfiguring labor (Munn, 2022). What matters is to shift the concept of the conflict between human labor and machine systems into collaboration.
To be committed to the collaborative task, it is important for individuals to decide on the approach and assign responsibilities for each task, matching between their capabilities and the requirements of the task/context (Cila, 2022). However, in human-robot collaboration, designers encounter challenges as a result of misunderstanding capabilities of the systems. This is because using automation in interactive systems requires considering potential changes in human activity and the new coordination demands on the human operators (Saadati et al., 2022). Over-trust or "complacency" can cause operators to neglect monitoring automation and fail to detect errors, especially when the system is highly but not perfectly reliable (Parasuraman et al., 1993). This behavior can lead to task degradation in humans, which can result in critical errors, such as pilots being forced to take manual control during a flight (Carr, 2015). Eventually, the responsibility for the consequences lies solely with people, and only people are responsible for determining how authority is delegated to automated systems (Bradshaw et al., 2013). Therefore, understanding the functioning of the system and the consequences is critical for the operator to determine to what extent the system does its job, allowing humans to take full control of the system with responsibility.
In this regard, task delegation needs more research as it's one of the design considerations in human-agent collaboration (Cila, 2022). it is necessary to affirm which tasks to delegate so that users can oversee the intention of automation systems, which should augment the skills of humans and not replace them (Cila, 2022). Therefore, there is a research opportunity to identify criteria of which tasks can be allocated to robots and which should be continuously performed by humans. Further, this approach can aid in recognizing situation where the transfer of control is necessaryand in effectively employing human judgment for critical decision-making tasks (Russell et al., 2015).
As understanding the user needs and the specific use context is crucial to identify these tasks (Cila, 2022), the context of Schiphol Airport Airside Operations is chosen, which is conducted within the Innovation Hub of Amsterdam Schiphol Airport.

[Case study of the Schiphol Airport Autonomous Airside Operations]
The highly dynamic environment of airports with a large number of different types of vehicles, aircraft, and people moving around calls for automation technology to cope with the complexity better. Autonomous airside operations aim to improve the efficiency and safety of airport operations by using advanced technologies to automate and coordinate different processes. However, regarding task delegation, the effective collaboration between human labor and automation systems in the airside remains under development, posing hurdles to the technology's adaptation.
To address the challenge above, the first step would be to identify fundamental attributes of collaborations with diverse autonomous airside operations. On the airside, various services and systems are interacting with people, that may be fully autonomous or not. Not merely categorizing the level of autonomy, it would be beneficial to identify different clusters of human activities and their interactions with automation systems (Bradshaw et al., 2013). To do so, researching the experiences of airside workers in collaborating with automation systems will be needed (Saadati et al., 2022). Not only would this improve the work environment and reduce high-stress levels, but it would also allow for the investigation of tacit needs in communicating with automated systems in the airside.

space available for images / figures on next page

introduction (continued): space for images

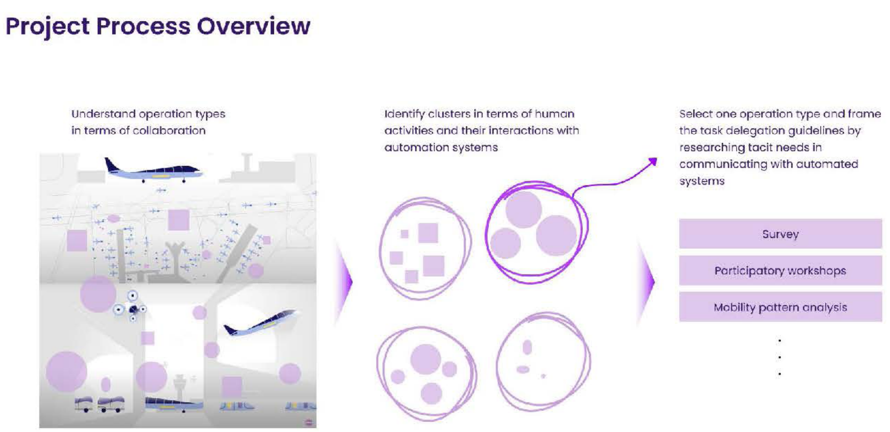


image / figure 1: Project process overview

TO PLACE YOUR IMAGE IN THIS AREA:

- SAVE THIS DOCUMENT TO YOUR COMPUTER AND OPEN IT IN ADOBE READER
- CLICK AREA TO PLACE IMAGE / FIGURE

PLEASE NOTE:

- IMAGE WILL SCALE TO FIT AUTOMATICALLY
- NATIVE IMAGE RATIO IS 16:10
- IF YOU EXPERIENCE PROBLEMS IN UPLOADING, COVERT IMAGE TO PDF AND TRY AGAIN

image / figure 2:

PROBLEM DEFINITION **

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

How might we design explicit task division guidelines to augment human skills when collaborating with automation systems in airfield operations?

Two key challenges must be addressed: 1) defining the collaboration types of automation systems in operations and 2) investigating the challenges workers face when delegating tasks to robots. To provide decision-making guidelines on task delegation for workers and automation systems, this research seeks to answer the following questions:

RQ1. 02 Problem Statement
How can we design explicit task delegation guidelines to augment human skills when collaborating with automation systems in airfield operations?
What to do
Research Questions

RQ2. What processes are needed in order to identify which tasks can be delegated to automated systems and tasks which must be performed by humans?

By answering these questions, the study aims to facilitate the creation of effective protocols for managing the complex and dynamic nature of airport operations, benefiting passengers, airlines, and other stakeholders. Additionally, this research expects to provide conceptual clusters of airside automation systems regarding human activities and a conceptual framework for designing task delegation in human-agent collaboration through a specific case study. Thus, the outcome expects to contribute to increasing the transparency of intentions between humans and automation systems.

ASSIGNMENT **

State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

The study investigates collaboration types in the airside automation systems and the experiences of airside workers in collaborating with automation to improve airport operations, aiming to provide task delegation guidelines for workers in using automation systems. The outcome could be a conceptual framework or guidelines for designing effective task delegation in human-robot collaboration in airside operations.

To tackle the assignment, a combination of qualitative and quantitative research methods will be conducted. First, in the research phase, a combination of desk research (e.g., literature review) and preliminary qualitative first-hand research (e.g., observations and interviews) through site visits in the airside will be conducted in order to answer RQ1. It will be a process of understanding the background of the airside operation context. And then, a specific operation type will be chosen, and this will involve participatory workshops, surveys, or other possible methods. This will lead to framing core insights to create guidelines for stakeholders, answering RQ2.

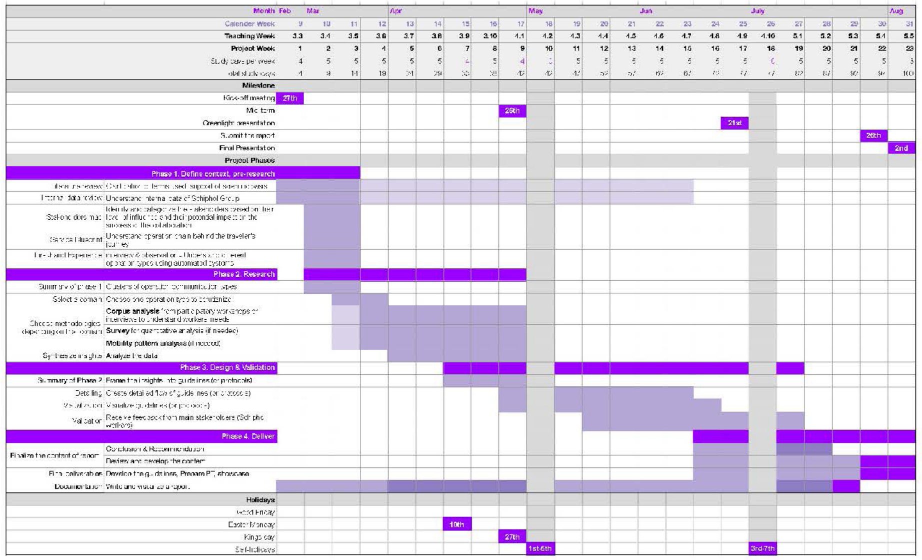
The expected outcome is guidelines or protocols, recommendations, and/or opportunity spaces for further development in the human-robots collaboration regarding task delegation in order to enhance the efficiency and safety of airport operation, improve the work environment for airside workers, and potentially reduce the workload and stress levels for human operators. Additionally, the research could provide insights for further development of automation technology that complements human skills and knowledge instead of replacing them, ultimately resulting in a more balanced human-robot collaboration in various automation industries.

TU Delft

PLANNING AND APPROACH **

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and 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 activities.

start date 27 - 2 - 2023 2 - 8 - 2023 end date



Bradshaw, J. M., Hoffman, R. R., Johnson, M., & Woods, D. D. (2013). The Seven Deadly Myths of "Autonomous Systems." IEEE Intelligent Systems, 28(3), 54–61. https://doi.org/10.1109/MIS.2013.70

Carr, N. G. (2015). The glass cage: How our computers are changing us. Norton & Company.

Cila, N. (2022). Designing Human-Agent Collaborations: Commitment, responsiveness, and support. CHI Conference on Human Factors in Computing Systems, 1–18. https://doi.org/10.1145/3491102.3517500

Munn, L. (2022). Automation is a myth. Stanford University Press.
Parasuraman, R., Molloy, R., & Singh, I. L. (1993). Performance Consequences of Automation-Induced "Complacency." The International Journal of Aviation Psychology, 3(1), 1–23. https://doi.org/10.1207/s15327108ijap0301_1

Russell, S., Dewey, D., & Tegmark, M. (2015). Research Priorities for Robust and Beneficial Artificial Intelligence. AI Magazine, 36(4), 105–114. https://doi.org/10.1609/aimag.v36i4.2577

Saadati, P., Abdelnour-Nocera, J., & Clemmensen, T. (2022). Co-designing Prototypes for User Experience and Engagement in Automation: Case Study of London-based Airport Future Workplace. In G. Bhutkar, B. R. Barricelli, Q. Xiangang, T. Clemmensen, F. Gonçalves, J. Abdelnour-Nocera, A. Lopes, F. Lyu, R. Zhou, & W. Hou (Eds.), Human Work Interaction Design. Artificial Intelligence and Designing for a Positive Work Experience in a Low Desire Society (Vol. 609, pp. 158–177). Springer International Publishing. https://doi.org/10.1007/978-3-031-02904-2_8

TU Delft

MOTIVATION AND PERSONAL AMBITIONS

Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... Stick to no more than five ambitions.

My master's program started with the motivation to explore the transition of experience between physical and intangible digital space. Working as a spatial and service designer in a spatial consulting firm enabled me to see new opportunities in AI, digital transformation, multiverse, digital twin, and so on. Even in designing space, It is inevitable that designers should equip with thorough research skills and knowledge about high technologies.

Through the Design for Interaction program at TU Delft, I expanded my perspective to the interaction point of view among humans, objects, the environment, and even robots. Questioning how designers can use AI encouraged me not just to have competence in dealing with technology but also to provoke critical thinking in terms of ethical issues and sustainability around technology.

During the third semester of my master's, I acquired analytic and strategic skills in addition to the regular DfI courses. By doing Social Venturing and Strategic Automotive, I learned how to formulate business strategies and ideas as a designer. Advanced Machine Learning for Design, Data Processing & Analytics enabled me to improve my scientific analytic skills and to obtain knowledge about how machine learning works and how designers use it ethically.

The research electives also guided me to clarify my interests in design research. Through the research about designing co-creation sessions with XR technology, I learned how to design a protocol with pertinent questionnaires to measure the different effects between conventional and XR sessions. In addition, In designing a design tool for city makers for another research elective, I learned how to find a way to research and consolidate insights from a wide range of literature.

Nevertheless, there are some competencies I want to acquire through the graduation project. One is a comprehensive understanding of the mobility industry for my future career. Through research in regard to mobility topics, I expect to have the professional knowledge to contribute to the industry, such as systems, operations, perspectives, and so on. Another desired skill I want to have is deeper understanding of interactions between humans and emerging technologies. Lastly, I expect to explore mixed methods in research, showing quantitative data as well as qualitative analysis. Although I learned some of the methods through the master's courses, this graduation project can be a great playground for me to simulate these learnings.

FINAL COMMENTS

In case your project brief needs final comments, please add any information you think is relevant.