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Robotiquette in Scandinavia

Establishing Design Guidelines for Restaurant Robots Within a Swedish Context

Master's thesis in Industrial Design Engineering

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CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2024
www.chalmers.se

Master's thesis 2024

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In collaboration with Merphi

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Print: Chalmers Digitaltryck

Acknowledgements, dedications, and similar personal statements in this thesis reflect the authors' own views.

Cover Illustration: The example concept of a restaurant robot using the established design guideline.

Abstract

This master thesis, which was conducted in collaboration with Merphi, set out to investigate what needs and requirements exist from dining customers and restaurant employees, to create acceptance for restaurant robots within a Swedish context.

The research was performed from multiple perspectives, including a literature study, semi-structured interviews, and observations, all of which generated valuable insights into the acceptance of restaurant robots in Sweden. The analysed material from the research phase was then translated into a first iteration of design guidelines to be further refined through an iterative design process. The design process consisted of six design sprints, each focusing on a predefined set of guidelines for the development of sub-solutions that later could be combined into a restaurant robot concept. This design process resulted in refined design guidelines and a robot concept showcasing an exemplified translation of the design guidelines. Further analysis of the design process led to the development of a novel suggested design approach. This approach aims to further facilitate the development of robots by providing a clear structure for transforming a service that has previously been perceived by the users to be centred around a human, into one centred around a robot. Finally, a smaller focus group consisting of expert robot designers was used to evaluate and identify further improvements in the design guidelines and the suggested design approach.

All the resulting insights are thought to help designers in the future develop robots that are to be accepted in a Swedish restaurant setting. The results were put into a web application showcasing the design approach, the design guidelines, the restaurant robot concept, and how they relate to each other to further aid future service robot designers.

Keywords
Restaurant robot, hospitality robot, human-robot interaction, technology acceptance, design approach

Acknowledgement

For this master thesis, there are several people whom we want to pay our gratitude to because without their contributions this master thesis would have not been possible.

First, we want to say a big thank you to the collaborating company Merphi for suggesting this master thesis from the beginning, which has provided us with new knowledge that we will bring to the future, but also for the support throughout the master thesis and the input that they have provided. A special thank you we want to say to Filip Sperr, for taking on the role of supervisor and contact person at Merphi.

Secondly, we want to say thank you to some special people at Chalmers University. First, to the students at Industrial Design Engineering who always were open to bounce ideas as well as to provide feedback and new insights. Second, to Lars-Ola Bligård, who took on the role of examiner for this master thesis, and who always took his time for discussion. Last, but certainly not least, our supervisor Fredrick Ekman. Fredrick provided feedback continuously throughout the thesis with our every second-week tutoring session, challenging us to make the best possible outcome, and he was never more than a phone call away when we needed input. An especially big gratitude to you!

Finally, a big thank you to all the people who took their time to participate in the user research, cause without you we would not have gained so many insights to the topic at hand which led to the results. Nobody is mentioned, but no one is forgotten.

Thank you all!

Emrik Andersson

Filip Takvam

Vocabulary

HRI	Abbreviation for *Human-Robot Interaction*
RtD	Abbreviation for *Research through Design*
AI	Abbreviation for *Artificial Intelligence*
UI	Abbreviation for *User Interface*
CMF	Abbreviation for *Colour, Material, Finish*
Abstraction Level	The level of detail and complexity in which an object or system is described. A lower abstraction level means it is described in more detail.
Machine Learning	A subset of artificial intelligence that enables systems to learn and improve itself (through a process called training), without the explicit need for programming definite instruction.
System	System can be seen as an organized network of multiple communicating entities, that either could be abstract (e.g. rules or flow of information) or tangible (e.g. a computer or a robot).

The Use of AI

This section is written to maintain full transparency of how AI has been used in the project.

As of 21 December 2023, Chalmers University of Technology has published new regulations on the use of AI tools within the scope of master thesis work. These state that the examiner (in this case Lars-Ola Bligård) is the one to decide how and to what extent AI tools are allowed to be within the scope of this work. The regulations continue stating that tasks such as generating text and conducting data analysis are allowed, as long as it is done “in a responsible and transparent manner” (Chalmers University of Technology, 2023b).

Multiple studies, mainly surrounding the tool ChatGPT by OpenAI, have highlighted that AI tools could be used to enhance the quality, as well as increase the efficiency of which academic and scientific papers are written (Huang & Tan, 2023; Imran & Almusharraf, 2023; Lingard, 2023). However, as pointed out by Chalmers there is a risk of plagiarism and/or copyright infringement when using AI tools. This is supported by (Huang & Tan, 2023) and therefore is good to be aware of. However, they continue by stating that the use of AI tools does not inherently increase the risk of plagiarism, and instead on how the content is used as well as attributed.

For this master thesis, our aspiration was to use AI as a tool/assistant for grammar check, as well as rewriting small parts of our own written texts. This has the potential to increase the quality, as well as increase the efficiency of the writing process itself. Rewriting could include making the language more concise and precise and sound more coherent if written by different authors (Emrik and Filip in this case). Due to the risks associated with the use of AI tools stated above, a cautious approach has been taken when reviewing the output.

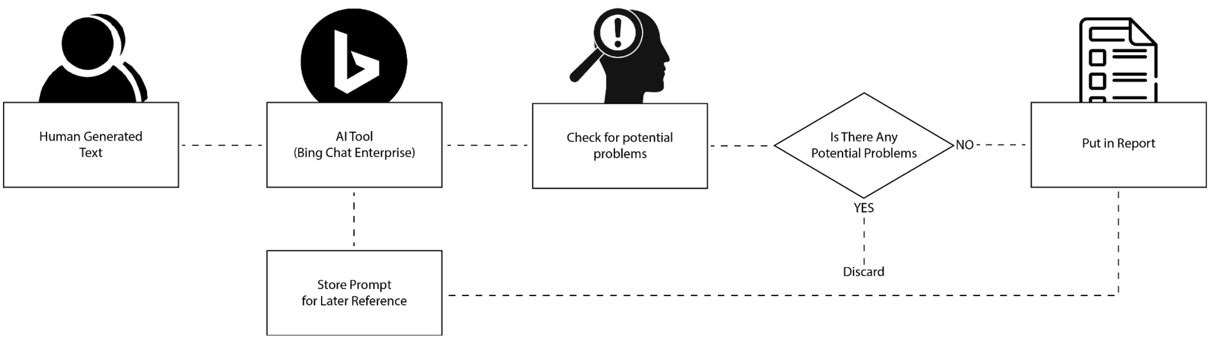

Figure 1 - Workflow of the use with AI.

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1
Introduction

1.1 Background

In the hospitality sector, which includes hotels and restaurants, employers have faced challenges in recruiting employees following the easing of the COVID-19 pandemic restrictions. This is due to the layoffs during the pandemic, where people instead choose to study or leave for other professions, making it difficult to rehire employees (Analysavdelningen, 2023). Today, some of the companies affected by this problem are turning to robotic solutions to handle the labour shortage. Thus an increase in automation is expected in hospitality professions, such as restaurants, to meet consumers' needs and expectations (Swedish Industrial Robot Association, 2022). In a study made by Filieri et al. (2022), an indication was found for a shift in customer perceptions within a restaurant setting. Individuals in the study generally reported positive interactions with robots, expressing enjoyment in being served by them. This was in contrast with prior opinions where customers often felt uneasiness and discomfort in similar situations.

However, to be successful it is essential to understand which tasks are suitable to assign to the robot in order to provide acceptance from both the customers' and the employees' perspective (Seyitoğlu et al., 2021a). Choi & Wan (2021) pointed out that there exist cultural differences that affect what impact certain functions and features have on user satisfaction. This has been substantiated by multiple studies that have been performed on the topic of service robots. All of these studies agree and have stressed the fact that there are cultural aspects that need to be considered, as they affect the human-robot Interaction (Bartneck et al., 2005; Jembere et al., 2023; Korn et al., 2021; Li et al., 2010). KrASIA Connection (2023) illustrates this by giving examples that robots are being designed in a compact manner to accommodate the narrow spaces found in restaurants in Japan and Hong Kong. Continuing, they provide the example that the robots in Japan often have an adorable aesthetic, reflecting the country's 'kawaii' or cuteness culture. However, it lacks research on how hospitality robots should be designed to provide acceptance in a Swedish restaurant context. This includes what functions should be assigned to the restaurant robot, as well as how these functions should be embodied.

1.2 Aim

The primary aim of this master thesis was to establish *design guidelines*. These were to be used for the development of hospitality robots in a restaurant setting, specifically tailored to a Swedish context. Focus was put on what needs and requirements exist from employees' and dining customers' perspectives, as well as what effect the Swedish cultural and social landscape has on the design of hospitality robots. To provide a deeper understanding of the established design guidelines, the master thesis involved creating a concrete design concept that exemplifies what the adaptation of the design guidelines could lead to.

1.3 Research Questions

1. What are the specific needs and requirements of users (dining customers and restaurant employees) in a Swedish restaurant setting, for a successful implementation of hospitality robots?
2. What design guidelines can these needs and requirements from users be translated into, which can act as support for designers creating a robot that is to be accepted in a Swedish restaurant setting?
3. How can these design guidelines be embodied in a design concept, to provide user acceptance?

1.4 Robot Definition

When people hear the word *robot,* they most probably already have a mental model of what it is (its appearance, behaviour etc.), and these could be shaped in various ways. One way could be for example by characters in movies (Banks, 2020). Therefore, it is important to establish a shared comprehension of what a hospitality robot is. As stated by the ISO Definition, ISO 8373:2012 §2.6, the term *robot* is an "*actuated mechanism programmable in two or more axes (4.3) with a degree of autonomy (2.2), moving within its environment, to perform intended tasks*" (International Organization for Standardization, n.d.). In the same standard, it is further defined in §2.10 that a *service robot* is a "*robot (2.6) that performs useful tasks for humans or equipment excluding industrial automation applications",* and in §2.12 that a *professional service robot* (the category of which a hospitality robot would fall into), is a "service robot (2.10) used for a commercial task, usually operated by a properly trained operator (2.17)".

In summary a hospitality robot from here on be referred to as an *actuated mechanism programmable in two or more axes, moving within its environment, to perform useful tasks for humans or equipment excluding industrial automation applications, operated by a properly trained individual.* As the project is about hospitality robots in a restaurant setting, the term *restaurant robot* will be used to clarify its context.

1.5 Restaurant Segmentation

There are multiple ways of segmenting restaurants based on service, food, and other descriptive factors, such as the *human touch.* Summarized, the human touch can be described as a sort of situational awareness of a human regarding, for example, the ability to read people's emotions, timing, and other implicit knowledge that comes with life and work experience. To create a more generalized segmentation, inspiration was taken from the article Types of Restaurants (2023) and three main segments were identified based on similarities during service interactions. To be noted, this segmentation does not cover all types of restaurants and there are instances where the lines between the segmentation become blurry. Instead, these segments were created to provide a simplification of different types of restaurants relevant to the master thesis, ensuring a shared understanding of what differentiates them.

Quick service

This segment includes categories such as fast-food restaurants that typically focus on the physiological need for food and where guests expect little to no personalized service. Generally, this segment possesses a low level of human touch within the service.

Full-service

This segment covers most restaurants that all share a similar service foundation. Here guests are usually seated and serviced by one employee throughout the entire visit. This includes a broad spectrum of restaurants with varying prices, food- and service-quality. This segment possesses a higher level of human touch as the server is more present throughout the visit.

Fine dining

Fine dining shares many similarities with full-service restaurants but with higher formality, price, and expectations from the guests. These restaurants often incorporate additional elements not typically found in full-service restaurants. For instance, fine dining service employees might plate or finish the dishes in front of the guests. This engagement results in an even higher level of human touch as the server is further involved in the restaurant experience.

1.6 Delimitations

- The platform of the robot was predefined, meaning that certain tasks were not to be considered. To further give the readers context of the platform, defined in conjunction with the collaborating organization, the parts mainly involved are briefly described in the list below:
    - In-hub motor wheels with encoders: These motors enable the movement of the robot. The motors themselves are placed within the wheel and include encoders to track the rotation, enabling precise control and localization.
    - Supporting wheels: In complement to the two in-hub motor wheels, the platform includes supporting wheels to stabilize the robot's movement, particularly during turns or when carrying heavy loads, to enhance overall manoeuvrability and safety.
    - Suspension: The platform includes a suspension system, which purpose is to absorb shocks and vibrations, for a smooth movement of the robot over uneven surfaces within the restaurant environment.
    - Motor controller: The motor controller is used to regulate the speed and direction of the robot's motors, translating output from the navigation system into physical movement.
    - Battery: The battery provides the power for the robot's operations.
    - Battery management system: This is used to monitor the battery's health, optimize the charging and discharging processes, as well as overall guarantee a safe operation of the battery pack.
    - Lidar: The lidar sensor's purpose is to scan the robot's surroundings, in order to create detailed 3D maps used for localization, obstacle detection, and route planning.
    - 3D Depth cameras: These cameras are aimed to capture depth information of the environment, for the robot to be able to interpret its surroundings better, by recognizing objects, and navigating effectively.
    - Accelerometer/Gyroscope: These sensors measure the robot's acceleration and orientation, providing essential feedback for motion control, stability, and navigation algorithms.
    - Navigation Microcontroller Unit (MCU): The navigation MCU has the responsibility to handle all the data required for the robot's navigation. This includes things such as plan routes, avoid obstacles, and reach designated

destinations efficiently. The actions which the robot is required to do is sent to the motor controller.

- MCU: The microcontroller unit (MCU) coordinates the operation of various subsystems, such as managing sensor data (not required for navigation), and executes low-level control tasks, contributing to the overall functionality and efficiency of the robot.

This type of robot platform in the context of a restaurant would according to International Federation of Robotics (2022) fall under the category of A1, rolling robot on wheels, and AP52, operating in an environment with public traffic (humans in this case) transportation of goods/cargo (dishes, beverages, food, etc.). Thus, there were certain limitations that needed to be considered when designing the robot. For example, since it has wheels it would not be able to walk up by stairs. However, in the different definitions, there is no clear indication of how the interaction between dining customers/employees and the robot should look, nor its appearance. This implies it is up to robot developers (designers, manufacturers etc.) to decide how this should be done and embodied.

- As the resources of this master thesis were limited, a fully functional prototype was not able to be developed.

1.7 Process Overview

As the work of this master thesis was design-oriented, and took a *Research through Design* (RtD) approach, which is all about gaining insights into ill-defined, complicated, and often future-oriented problems by practising and applying methods of the design profession (Godin & Zahedi, 2014), it consisted of a lot of wicked problems. By nature, these types of problems are filled by unknowns which could provide new challenges along the process, necessitating adaptation of the work. Therefore, at the beginning of the master thesis, it was concluded that linear ways of working would not be suitable, and instead, a more agile approach was preferred to allow for more iteration and experimentation.

Two popular methodologies that incorporate the agile mindset are Design Thinking (Interaction Design Foundation - IxDF, 2016) and Scrum (Drumond, n.d.). Takeshi (2021) has stated that these two frameworks can be used together and take advantage of each other's strengths. Design Thinking, which consists of the five phases Empathize, Define, Ideate, Prototype, and Test, have been criticized by Takeshi who points out weaknesses in the execution phase of prototyping and testing (to some extent also the ideation). Continuing, he states that these phases are treated too simplistically and that more time should be put into them. According to Takeshi this is where Scrum is most applicable, with concepts such as *Product Backlog, Sprint Backlog,* and *Daily stand-ups*, all of which allows the work to steadily progress. It also provides a disciplined framework for iterative and incremental development. However, Scrum, according to Takeshi, lacks a depth of thinking and understanding of what to develop. The process of this master thesis was therefore structured in a way that combined these two frameworks as proposed by Takeshi (2021).

The master thesis can be seen as structured in five primary phases: Empathize, Define, Ideate, Evaluation, and Present (an overview of the phases can be seen in Figure 2).

- During the *Empathize phase*, an understanding of the problem was formed. This included performing a literature review but also gaining insights from the different stakeholders' perspectives using interviews and observations. It was important to set aside previous assumptions and acquire real insights into the different stakeholders' needs and requirements (Interaction Design Foundation - IxDF, 2016).

- During the *Define phase*, all the collected data from the empathize phase were compiled. This was done by analysing the data from different perspectives to identify patterns, themes, and insights. The goal was to distil the information into a set of clearly defined insights, and later design guidelines to support the Ideate phase.
- During the *Ideate phase*, different ideas and solutions based on the design guidelines and insights were generated. As seen in Figure 2, the ideate phase was divided into two sub-phases.
  - Top-down ideation – The initially defined design guidelines were used to iterate concepts on a *high abstraction level* (concepts with low detail and complexity level). This refers to a broader and more general ideation phase to gain a better understanding of what aspects to consider when, in this instance, designing a restaurant service robot. These high abstraction level concepts were then put into the product backlog (prioritized list over the possible features and functions) for the upcoming design sprints.
  - Bottom-up ideation – This subphase involved taking the high abstraction level concepts and refining them to a *low abstraction level* (concepts with higher detail and complexity level). Each aspect of the robot is more thoroughly ideated in this phase, and more detailed sub-solutions were created. This phase was iterative and consisted of several cycles called design sprints (from the scrum methodology). In each design sprint, a specific set of features were worked on. Each sprint consisted of the following four stages:

    1. Planning, decide on what backlog items should be prioritized within the sprint, what goals are to be reached, and how to get there.
    2. Implementation, the execution part of the sprint where the results are generated.
    3. Review, where different stakeholders review whether the goals are reached.
    4. Retrospective, to identify success and possible improvements (Wrike, n.d.).

  Throughout this project, the various design sprints introduced a systematic approach by addressing smaller segments of the design guidelines in each iteration. This approach not only streamlined the workflow but also enabled continuous refinement of the design guidelines and evaluation of its ability to support the overall design process.
- During the *Evaluation phase*, the refined design guidelines were evaluated by designers, experienced in human-robot Interaction.

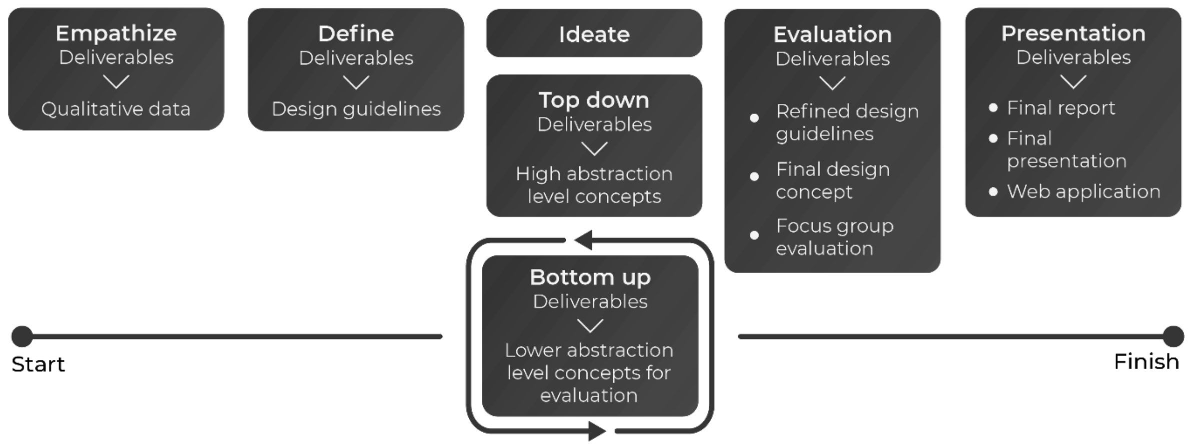

Figure 2 - Process Structure.

2
Methods

In this chapter, the different methods used throughout the master thesis are presented. The aim is to provide readers unfamiliar with any method mentioned in the rest of the report with a description of it and its purpose. For the convenience of the reader, the methods are placed in alphabetical order.

2.1 Brainstorming

Number of participants: Minimum 1 person.
Outcome: Ideas and solutions on a specified problem or topic (written or visualized).

Brainstorming is a method used to create a vast number of ideas and possible solutions when ideating (Wikberg Nilsson et al., 2015). The format in which the ideas are presented can differ, but the main concept is to choose a suitable medium that is both effective and efficient for the problem at hand. Examples of methods that can be seen as a subcategory of brainstorming are Brainwriting and Braindrawing (Wikberg Nilsson et al., 2015). These are also used to create a large quantity of ideas, either using words or sketching (as the names implies). This method can either performed individually, but also in groups to build upon each other's ideas.

2.2 Focus Group

Number of participants: Minimum 3 persons.
Outcome: Gathered opinions, insights, and feedback from participants on a specific topic.

A focus group can be described as a group interview, with the aim of gathering valuable opinions and insights from a specific group of users (Boeijen et al., 2020). This method can be used in multiple different phases of the project to facilitate a more creative environment for discussion. As the name implies, this method requires multiple people, as the purpose is to build upon each other's insights and questions and come up with new insights that were originally not thought of.

2.3 Grounded Theory Method

Number of participants: Minimum 1 person.
Outcome: Insights into, and contribution to the current understanding of a specific subject area, which is grounded in reviewed research.

The Grounded Theory Method was introduced by Wolfswinkel et al. (2013) and is a method for structuring literature reviews. It consists of a five-stage process, including the following stages:

- Define the scope of the literature review and decide on criteria for inclusion and/ or exclusion of articles.
- Search through databases to find existing articles matching the defined scope. Potential iterations of the criteria can be made at this stage as more knowledge is gained.
- Select the final data set by filtering out articles that do not fit the criteria.

- Analyse the selected articles and highlight passages deemed relevant for the defined scope. Excerpts from different articles can then be coded and categorized into different themes.
- Present the findings and insights gathered in the analysis phase in a structured way.

This five-stage process allows for a systematic and in-depth analysis of the existing literature. By following this approach, a theory grounded in the reviewed research can be developed.

2.4 HTA (Hierarchical Task Analysis)

Number of participants: Minimum 1 person.
Outcome: An understanding of, as well as a graphical representation of a hierarchical structure of, all the actions that a user must take to complete a certain task.

HTA (Hierarchical Task Analysis) could be used to break down tasks into smaller, more manageable elements. Preferably it is graphically visualized in a hierarchical structure that represents relationships and dependencies between these elements (Bligård, 2015). It is a good tool for mapping and understanding the actions and the steps users must take to complete a task within a given context.

2.5 Image Boards

Number of participants: Minimum 1 person.
Outcome: A collage of visual elements and an understanding of the desired design direction.

An image board is a collection of visual elements (photos, illustrations, etc.) that is put together in a collage. The image board's purpose is to create a common understanding of the desired design direction of the aesthetics, context, etc. within the design team, as well as work as a source of inspiration (Wikberg Nilsson et al., 2015).

2.6 KJ-analysis (Affinity diagramming)

Number of participants: Minimum 1 person.
Outcome: Comprehensive overview of data through thematic groupings based on similarity and patterns.

KJ analysis, also known as affinity diagramming, is a method developed by Jiro Kawakita for synthesizing large amounts of data in order to gain a comprehensive overview. The method builds on a bottom-up strategy that involves recording individual data points (often citations from collected text data) on post-it notes, grouping them based on themes, and gradually building up from details to the overall picture. An advantage of using this method is it allows for the emergence of groupings during the analysis process, rather than predefining them (Bligård, 2015).

2.7 Market Overview

Number of participants: Minimum 1 person.
Outcome: Insights of how the current market looks (in this case restaurant robots).

To get a sense of how the current market looks, what could be best described as a market overview could be performed. For this particular case, this involved searching on the web with the keywords *restaurant robot* and *hospitality robot. S*ubsequently, images were collected, and the main functions marketed by the reseller were listed. The objective was to identify common technologies and functionalities, along with their embodiment in currently available robots.

2.8 Morphological Matrix

Number of participants: Minimum 1 person.
Outcome: Complete solutions that were not originally thought of.

A morphological matrix is used to systematically combine sub-solutions to create more complete solutions (Wikberg Nilsson et al., 2015). The method is an effective and efficient way of creating a larger number of concepts, as well as sparking new ideas as the sub-solutions are combined in a way that was not thought of originally. A morphological matrix is often visualized through a table, where each row represents a particular feature, and each column represents a solution of the associated feature.

2.9 Observation

Number of participants: Minimum 1 person.
Outcome: Understanding of how users interact with a particular product within a context.

Observations can be used to study a specific user group interacting with a product in its right context, this can be either in a natural scenario or in a lab set-up. This method enables the designer to identify other factors and variables that influence the interaction and are hard to capture through other methods (Boeijen et al., 2020). There are multiple ways to conduct an observation, generally, it includes the following steps:

- Users are observed during a set period of time in a specific context.
- The observations are documented through, for example, recordings, pictures, notes, etc.
- Findings are analysed and conclusions are drawn.

The goal of an observation is to identify potential areas for product development and to understand user perception of intuitiveness within the product's design (Wikberg Nilsson et al., 2015).

2.10 Role-playing

Number of participants: Minimum 1 person.
Outcome: A better understanding of user interactions and experiences through acting out the interactions.

Role-playing offers designers a valuable technique to create user empathy. By actively simulating a user's perspective, designers can re-enact typical user scenarios. This re-enactment involves replicating the user's intended tasks and interactions within a specific context to create a deeper understanding of the user's journey. The aim is for designers to identify interaction flaws and potential solutions to enhance the user experience (Boeijen et al., 2020).

2.11 Scenario

Number of participants: Minimum 1 person.
Outcome: Depiction of user interactions to use as support when generating design ideas and criteria.

Written scenarios are a valuable method for expressing and illustrating user experiences within specific contexts. This method finds this method is usually applied during the initial phases of the design process. Scenarios can serve two primary functions:

- Identifying and Developing User Interaction Criteria: Scenarios can be used to explore potential user interactions with a product or service.
- Generating Design Ideas: Written scenarios can spark creative thinking and lead to the generation of novel design concepts.

Scenarios typically consist of a detailed description of an interaction involving a defined set of actors within a specific context. The aim is to capture a comprehensive range of user experience details, serving as a foundation for further discussion and design refinement (Boeijen et al., 2020).

2.12 User Interviews

Number of participants: 2 persons.
Outcome: Insights from individuals at a deeper level on a specific topic.

User interviews are used to gain insights from users at a deeper level. The insights could be their opinions, emotions, needs, etc. about a certain topic (Wikberg Nilsson et al., 2015). Semi-structured interviews are the most frequently used interview technique, and it is a well-tested and effective way to gain in-depth insights from participants by allowing for exploration while also adhering to a pre-determined set of open-ended questions (Kallio et al. 2016).

Scenarios typically consist of a detailed description of an interaction involving a defined set of actors within a specific context. The aim is to capture a comprehensive range of user experience details, serving as a foundation for further discussion and design refinement (Boeijen et al., 2020).

2.13 Visualization

Number of participants: Minimum 1 person.
Outcome: Visual representations (in differing mediums) of different ideas, and solutions.

To visualize different ideas, as well as the final concept, different visualization techniques can be used throughout the design process. Different visualization methods are more or less appropriate depending on which phase the project currently is in, the activity being performed as well as on who it will be presented to. The most important thing is that it effectively communicates the ideas and drives the project forward by for example highlighting potential issues that are difficult to visualize purely theoretically. It is up to the designer to decide what method is suitable at the time of the project. Examples of visualization methods that are to be used during the project are:

- Sketching: Sketching is one of the most common visualization methods used by designers in the early phases of the design process as it allows them to explore various ideas and concepts quickly. Often pen and paper or digital drawing tools are used. Sketching primarily helps to convey things as basic shapes, proportions, and layouts, facilitating rapid ideation and communication of initial solutions and design concepts.
- Mock-ups: Mock-ups are prototypes, either in physical or digital form, that represent a more refined version of the design idea. They can range from being a simple cardboard

model to a fully interactive digital prototype. Mock-ups allow designers and stakeholders to get a more tangible and better understanding of for example the scale, functionality, and overall look and feel of the design.

- Computer modelling: The way computer modelling is executed can differ (such as using CAD and polygon modelling), but it centres around creating a 3D digital representation of a design. This method allows for a higher fidelity exploration of form, structure, and spatial relationships within the design. The computer model can later be used as a foundation to create computer-generated images.
- Computer rendering: Computer rendering involves applying materials, textures, lights, etc., in a digital environment to a previously created computer model in order to generate (more or less) photorealistic images. The process/method enhances the visual presentation of the design, allowing different stakeholders to envision the final product more realistically. It can also be beneficial in the material and finish selection process, as you can get a sense of how it will be perceived in different lighting conditions and settings.

2.14 Weighted Evaluation Matrix

Number of participants: Minimum 1 person.
Outcome: Support in the decision-making process that is based on how well different concepts and/or solutions fulfil criteria.

To support the selection of which concepts to further develop in the later stages of the design process, a weighted evaluation matrix can be used. It ranks the different solutions against several desired selection criteria, that have been weighted depending on their assumed importance (Wikberg Nilsson et al., 2015). This allows certain selection criteria to play a larger role in the decision process. Important to notice is that the weighted matrix should be used as a guide, rather than a definite decision decider. It could also act as a way of finding weaknesses within each concept that should be targeted.

3
Literature review

This chapter will present how the literature review was executed in accordance with the grounded theory method, as well as present the results of the literature review. The results are structured as follows: a brief introduction to human-robot interaction which is followed by a concise overview of technology acceptance and rationalization of selecting two specific acceptance models. Subsequently, the literature review focused heavily on these two acceptance modes, each tailored to a specific user group, examining the influencing key factors. This was followed by a brief overview of the impact of culture on technology. Thereafter, a selection of factors concluded to be possible to affect through design was chosen and discussed in greater depth. Lastly, the chapter concludes with a few key takeaways on the topic of technology acceptance and related factors, in relation to the aim of the master thesis.

3.1 Procedure

A fundamental aspect of conducting a *basic literature review* involves gaining insights and contributing to the current understanding of a specific subject area. Machi & McEvoy (2009) highlights that the outcome and process may vary depending on the research questions, as well as the research praxis within the field in question. This literature review aimed to form an understanding of the existing academic literature on how restaurant robots may be accepted and consequently adopted.

Define

The first phase, define, included finding keywords relating to the research questions and aim of the master thesis. The main field of interest, as well as associated keywords, were:

- Technology acceptance:
    - Perceived Usefulness
    - Perceived Ease of Use
    - Trust
    - Extended technology acceptance model robot
    - Sweden
    - Cultural Dimensions
- Human-Robot Interaction
    - Hospitality
    - Restaurant
    - Anthropomorphism
    - Culture
- Function allocation
    - Human-Robot collaboration
    - Context

Search

The next phase, search, included searching for relevant papers using the keywords in the Define phase. This was done through the software *Publish or Perish,* a software that retrieves and analyse existing academic literature. The chosen database defined in Publish or Perish was Google Schoolar.

Select

In the third phase, select, the retrieved papers' titles as well as abstracts were read through, and papers that were deemed irrelevant were discarded. The next step in the selection process was to backward chain, meaning looking at the already existing papers' references to see if they covered similar topics.

Analyse

The fourth phase, analyse, included extracting excerpts (small sections of text) from the papers that were relevant and could be built upon to form a bigger picture. Using a method similar to the KJ-analysis/Affinity diagramming (Bligård, 2015), the excerpts were grouped based on similarity and gradually built up to a more objective and holistic perspective of different themes within the topics.

Present

The last phase, present, is about demonstrating a deeper understanding of the findings of the analyse phase and presenting them to the reader. In this case, the findings are structured and presented in the Literature Review section of the master thesis, with main takeaways to keep in mind in the progression of the master thesis.

3.2 Results

Technologies, including robots, are more and more being introduced into today's workplaces (Parker & Grote, 2022) and restaurants are not an exception (Seyitoğlu et al., 2021b). However, Saari et al. (2022) have highlighted previously conducted research on the integration of robots as co-workers in restaurant settings is not without challenges. For a restaurant robot to be adopted, it is important to create user acceptance towards the technology. If the acceptance is not sufficient it may be rejected or not used often, decreasing job satisfaction which ultimately could lead to a loss in performance (Mlekus et al., 2020).

Human-Robot Interaction

Human-robot interaction (HRI), is a discipline which is to many considered relatively new, but due to the rapid development within the physical aspects of robotics, and especially the integration of more advanced systems (due to development within machine learning, etc.), it has become increasingly more relevant and adopted (Dautenhahn, 2014). Important to notice that HRI is considered interdisciplinary, with many practices involved including design, computer science, engineering, sociology etc. As its name suggests, it focuses on the interaction between humans and robots. HRI draws a lot of similarities to Human-Computer Interaction (HCI), but due to its need to be embodied and placed in the real world adds a higher level of complexity (Feil-Seifer & Matarić, 2009).

There are many definitions out there of HRI, but one that summarizes many of the papers and insights in a good way is by Dautenhahn (2014) and is as follows; "*HRI is the science of studying people's behaviour and attitudes towards robots in relationship to the physical, technological and interactive features of the robots, with the goal to develop robots that facilitate the emergence of human-robot interactions that are at the same time efficient (according to the original requirements of their envisaged area of use), but are also acceptable to people, and meet the social and emotional needs of their individual users as well as respecting human* *values*". In the same paper, Dautenhahn (2014) highlights the difficulties with HRI and states that the concept of a robot can be seen as a *moving target* as people's perceptions of robots and their capabilities are constantly evolving.

Stakeholders – Interaction Diagram

When looking into the restaurant context, multiple users need to be considered. Koerten & Abbink (2022) have proposed interaction diagrams as a way of visualizing and predicting the effect the introduction of restaurant robots may have from a more holistic perspective. The interaction diagram includes the employees, customers, robot, and organisation, all of which can be seen in Figure 3. This literature review has specifically focused on the acceptance of customers and employees since they are the actual users directly affected as individuals by the introduction of robots in the context of restaurants. With this being stated, we note that the organisational level plays an important role when it comes to the implementation and overall usage of restaurant robots, as well as influencing customers' and employees' acceptance to a degree.

However, one factor missing in the interaction diagram is the explicit mention of the effects of culture. Multiple studies that have been performed on the topic of service robots (within different contexts and not only within restaurants) have stressed the fact that there are cultural aspects that need to be considered, as they affect the human-robot interaction (Bartneck et al., 2005; Jembere et al., 2023). Therefore, in the spirit and the desired direction of the master thesis, the context (which includes factors such as cultural norms) has been added to the original framework to emphaasize the importance of these factors.

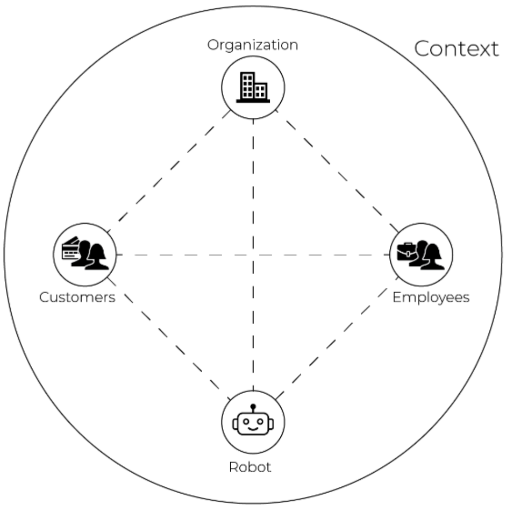

Figure 3 - Modified Interaction Diagram(redrawn from Koerten & Abbink, 2022).

Acceptance Models

There are multiple ways of studying how users may accept and adopt technologies, and there are suggestions that different acceptance models are more or less appropriate depending on which stakeholder is being considered. Therefore, from the employees' perspective, the technology acceptance will be considered from *The Intelligent Systems Technology Acceptance Model* – ISTAM (Vorm & Combs, 2022). See Figure 4. This model is based on one of the historically most prominent models used to predict technology acceptance, known as the Technology Acceptance Model (TAM), which was first introduced by Davis (1989). It was introduced to try to determine why people choose to accept or reject IT solutions specifically in workplace situations. Since its first introduction, the TAM framework has been proven to be applicable outside of the computer field (Svensk & Jernetz, 2023). However, the authors of the ISTAM model claim that practitioners within the Human-Computer Interaction must reconsider their old understanding of factors affecting technology acceptance and incorporate trust as a determinant with the new more intelligent systems, such as a restaurant robot may be considered depending on how it is being designed. They further substantiate their claim by stating that multiple previous studies have concluded that trust must be integrated into the more intelligent systems, or otherwise it would be rejected by the public.

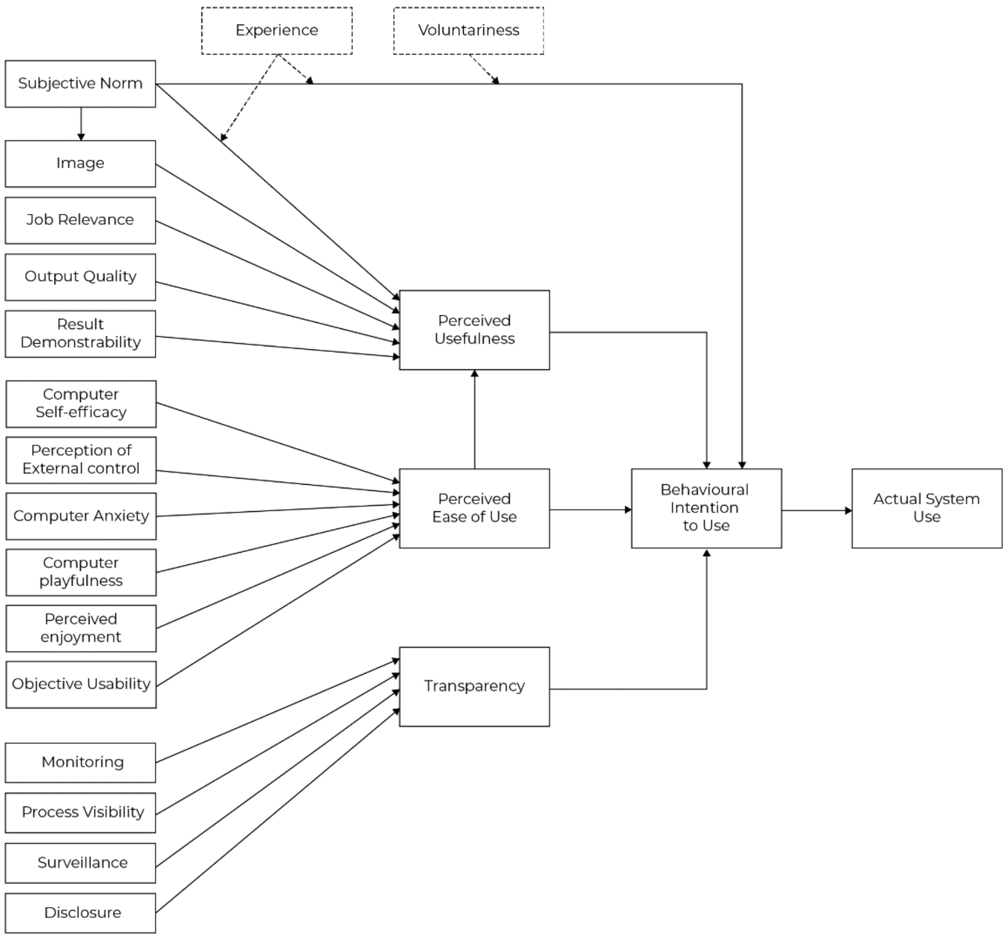

Figure 4 - ISTAM Model (redrawn from Vorm & Combs, 2022).

From the customers' perspective, the *AI Device Use Acceptance* – AIDUA model (Figure 5) will be in focus. It was introduced in the paper *Consumers acceptance of artificially intelligent (AI) device use in service delivery* (Gursoy et al., 2019), which called attention to the need for a model to understand customers' thought processes in accepting or rejecting AI devices, specifically in *service encounters*. The model has since then been validated successfully by using it to evaluate an AI robotic device for service delivery in a hotel setting (Lin et al., 2020). Moreover, Lin et al. (2020) noted that the same robot could have varying levels of acceptability depending on its application and context.

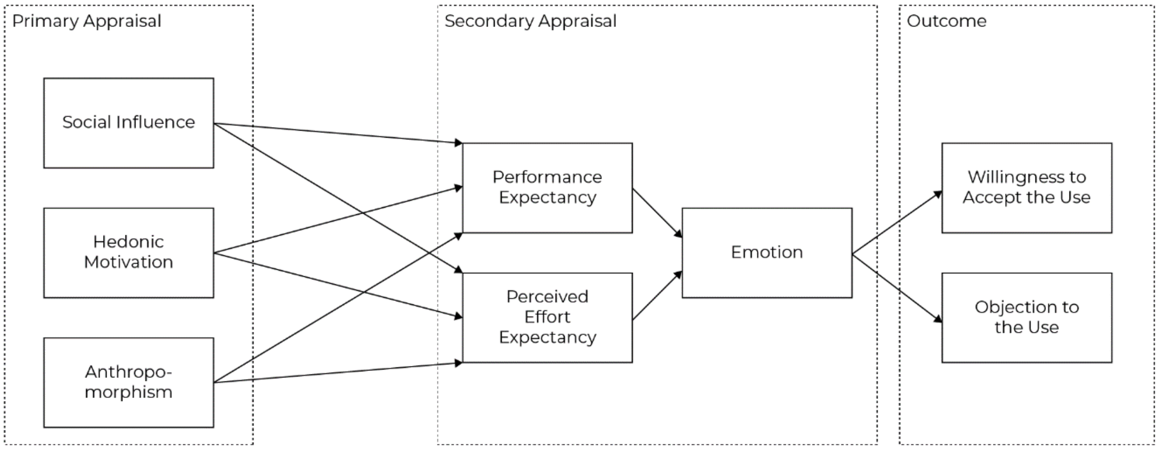

Figure 5 - AIDUA Model (redrawn from Gursoy et al., 2019).

Terminology for the Acceptance models

In these acceptance models, the term system is used frequently. A system itself can be seen as an organized network of multiple communicating entities, that either could be abstract (e.g. rules or flow of information) or tangible (e.g. a computer or a robot). A system can also exist at different abstraction levels (level of detail), and it is determined by what the one describing the system includes. Furthermore, the definition of what is included or not is referred to as the system limit. An example of a common system is the human-machine system, which is describing the interplay between a human and a machine (Bligård, 2015).

In the acceptance models, there are two key terms essential to clarify in order to follow along with the rest of the literature review. These are the terms *determinants* and *moderators*.

- Determinant: A key factor directly influencing the individual user and is used in the acceptance models to explain why the user chooses to accept or reject certain technologies.
- Moderator: Factor not directly influencing the individual user, but rather modify the significance/effect of relationships between the different determinants.

In the figures related to the different acceptance models, the determinants will have a solid border, and moderators will have a dashed border to separate them more easily for the reader. An example can be seen in Figure 6.

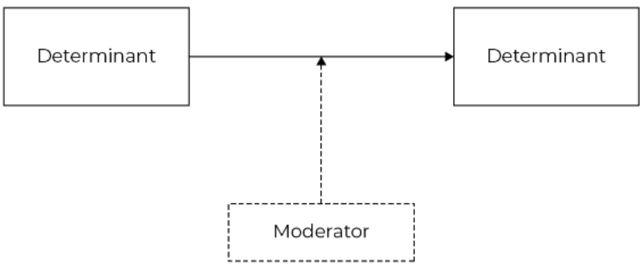

Figure 6- Example of determinant and moderator.

Acceptance from Employees' Perspective – ISTAM

As previously mentioned, the ISTAM model is based on the widely adopted TAM model. The original TAM model presented by Davis (1989) considered *Perceived Usefulness* and *Perceived Ease of Use* affecting the *Behavioural Intention to Use*, and consequently *Actual System Use* to be the most important determinants for technology acceptance.

- Perceived Usefulness: This refers to the user's perception that the system will enhance their job performance and make their tasks easier. If the Perceived Usefulness is higher, the more likely it is to be accepted by the user.
- Perceived Ease of Use: This refers to the user's perception of how easy the system in question is to use. The easier it is perceived to use, the more likely it is to be accepted. There exists a one-way relationship between Perceived Ease of Use and Perceived Usefulness, as in if users feel the system is easy to use, they are more likely to find it useful.
- Behavioural Intention to Use: This refers to the user's intention to adopt and use the system in question. If the intention is higher, it is more likely to be used.
- Actual System Use: This refers to the users' actual use in the real world.

As previously mentioned, Vorm & Combs (2022) have stated that trust needs to be considered when studying technology acceptance of more intelligent systems. By comparing the three most prominent trust models (Hoff & Bashir, 2015; Lee & See, 2004; Mayer et al., 1995), Vorm & Combs (2022) identified *Transparency* to be a determinant for technology acceptance and subsequently added it to the already existing TAM model.

- Transparency: This refers to users' possibility to access and assess information about the system. An appropriate level of transparency will lead to a higher Behavioural Intention by the users.

Important to note is that according to Vorm & Combs (2022), transparency could be somewhat ambiguous in academia due to the many different definitions that exist in the literature. Nevertheless, despite the definition that is chosen, the main takeaway is that users often struggle to understand the output of systems with a low level of transparency making it a key factor for the trust that the user puts in the system.

ISTAM - Determinants of Perceived Usefulness

Perceived Usefulness was shown in several empirical studies to be a strong driver for Behavioural Intention. Thus, in the revised TAM2 model, Venkatesh & Davis (2000) wanted to understand the determinants influencing this determinant as well as how it may change over time. Consequently, they validated five determinants affecting Perceived Usefulness which could be divided into how users are being affected by the social environment (social influence processes) and how users' thinking processes influence how they make decisions (cognitive instrumental processes). These determinants are according to the authors of the ISTAM model:

- Subjective Norm (Social influence process): The extent to which a user believes that the majority of the people important to them think they should choose to use or not use the system.
- Image (Social influence process): The extent to which a user perceives that their status will improve in the social setting if they choose to use the technology.

- Job Relevance (Cognitive instrumental process): The extent to which a user perceives that the system is appropriate for the user's work.
- Output Quality (Cognitive instrumental process): The extent a user believes that the system will perform its task(s) at work to a good level.
- Result Demonstrability (Cognitive instrumental process): The extent to which the users perceive that the results of the use of the system are demonstrated to them. This includes how tangible, observable, and communicable the results are.

Except for these five determinants, Venkatesh & Davis (2000) highlight two moderators named *Voluntariness* and *Experience* which influence the social influence processes. Continuing, they state that the subjective norm will have a direct influence on Behavioural Intention within a mandatory setting but not in a voluntary one. Thus, they argue depending to which extent the users perceive that the decision to implement the system is non-mandatory, will have a direct impact on Behavioural Intention to use the system.

Continuing, Venkatesh & Davis (2000) highlight that subjective norms have a direct effect on the intention to use the technology in a mandatory setting, but as the user gains experience with the technology its effect will decrease. It could also be argued that subjective norms' effect on Perceived Usefulness will weaken over time as the technology is used. This as the users then instead will rely on their first-hand experience rather than the social cues.

ISTAM - Determinants of Perceived Ease of Use

Similarly, to determine the determinants of Perceived Usefulness, Venkatesh (2000) wanted to find the determinants that influenced Perceived Ease of Use. These determinants were validated:

- Computer Self-efficacy (General computer Belief - Anchor): The extent to which the users believe in their own skills to be able, with a computer, to perform certain tasks/jobs.
- Perception of External control (General computer Belief - Anchor): The extent to which a user perceives that there exists technical support and an organization to assist the use.
- Computer Anxiety (General computer Belief - Anchor): The extent to which a user may feel anxiety and fear when having to deal with computers.
- Computer playfulness (General computer Belief - Anchor): The extent to which the user possesses a "playful" behaviour when interacting with a new system. Users who perceive it as fun will tend to overlook difficulties embedded in the systems.
- Perceived enjoyment (System-specific Belief - Adjustment): The extent to which the user perceives joy in using the system, without considering any performance-related consequences arising from the use of the system.
- Objective Usability (System-specific Belief - Adjustment): The actual (not perceived) and comparable effort it takes to complete tasks using the system.

Venkatesh (2000) divided the determinants into *Anchors* (initial perceptions of users that are based on their existing beliefs, experiences, and external cues) and *Adjustments* (factors that adjust the users' initial perceptions). According to Venkatesh (2000), individuals tend to rely on the anchors in the decision-making processes in cases of lacking information. Continuing, after new information is presented to the user, often associated with the direct experience derived from the use of the system, the individuals tend to adjust their judgment based on their reflection. However, they also tend to depend on their initial anchoring.

According to Venkatesh (2000) *Computer Playfulness*, *Perceived Enjoyment*, and *Objective Usability* are all moderated by experience. Computer playfulness is expected to lower its impact on Perceived Ease of Use with experience, while Perceived enjoyment and Objective Usability's importance is expected to increase, and so is its effect on Perceived Ease of Use. Other relationships between different determinants, as well as moderators that were proposed and empirically tested are:

- Perceived Ease of Use effect on Perceived Usefulness, moderated by Experience: Users are expected to consider Perceived Ease of Use while shaping their perceptions of how useful the system is. It is also argued that with experience associated with direct use of a system, the users will reevaluate how difficult the system is to use.
- Computer anxiety effect on Perceived Ease of Use, moderated by experience: Users' computer anxiety effect is expected to decrease with experience associated with direct use of a system, and instead the system-specific determinants will increase its effect on the Performance Expectancy.
- Perceived Ease of Use effect on Behavioural Intention, moderated by experience: The extent to which Perceived Ease of Use affects Behavioural Intention is expected to drop as the users' experience associated with use increases. This is due to Perceived Ease of Use having a big impact in the beginning, as often the difficulty of the system' is seen as a barrier. However, when the barrier has been overcome, Perceived Ease of Use has played out its role. Consequently, Perceived Ease of Use is considered less important in influencing Behavioural Intention.

ISTAM - Determinants of Transparency

According to Vorm & Combs (2022), enhanced trust will not only affect Behavioural Intention directly but also increase Perceived Usefulness and Perceived Ease of Use. Vorm & Combs also identified four determinants for transparency which were derived from Bernstein (2017). These are interpreted as follows:

- Transparency for Monitoring: To the extent the system displays information about the state of the current activity or task.
- Transparency for Process Visibility: To the extent that allows the user to understand the underlying processes that the system includes.
- Transparency for Surveillance: To the extent to which the system implements moment-moment surveillance to ensure a clear and observable oversight of the relevant activities or individuals.
- Transparency for Disclosure: To the extent that the system shows the types of data being used, as well as its origin.

Despite highlighting these four determinants, Vorm & Combs (2022) do also highlight that the terminology is not the most essential and that different strategies may have to be applied for integrating transparency, and/or trust, depending on the field of interest. Important to note is that there are not any specified moderators like the previously presented acceptance models, and the model has not been widely adopted. However, it does have great similarity in relationships presented by the more adopted and extended TAM framework by Wu et al. (2011), thus in our opinion making the ISTAM model applicable and substantiated. The main difference is the authors of the ISTAM have identified the main determinant being Transparency in the most adopted trust models.

Acceptance from Customers' Perspective – AIDUA

As previously stated in this literature review, the customers' acceptance of the restaurant robots will be studied with the AIDUA model as a foundation. Hospitality robots in general (not only for the restaurant context) are increasingly adopting Artificial Intelligence (AI) to handle more complex tasks. Chi et al. (2023) have pointed out that the implementation of the technology will fail if there is not a high level of acceptance of the AI. Continuing this topic, Gursoy et al. (2019) state that previous traditional TAM(s) may explain the acceptance of AI to a certain degree, but that these were originally made for non-intelligent technologies. Gursoy et al. (2019) claim that two main variables in conventional TAM models, Perceived Ease of Use and Perceived Usefulness, become obsolete when examining technology acceptance in a service encounter from a customer's perspective. AI devices that possess human-like behaviour require minimal effort to learn, making Perceived Ease of Use irrelevant and are designed to mimic the function of a human thus Perceived Usefulness will not be relevant to evaluate the willingness to adopt (Lu et al., 2019).

AIDUA consists of three phases *Primary Appraisal*, *Secondary Appraisal,* and *Outcome Stage* (Gursoy et al., 2019). Continuing, it is suggested that customers in service encounters evaluate the relevance, as well as the importance, of an AI Device in the Primary Appraisal phase based on three determinants.

- Social Influence: To the extent to which the customer's social group perceives the AI devices to be relevant and conform to the group's norms. Similar to the presented ISTAM model, the social influences are the greatest in the beginning but diminish over time as the customer gains knowledge to build their own more informed decision.
- Hedonic Motivation: To the extent to which the customer expects to feel joy and pleasure from utilizing the AI device. The author highlights several studies that claim that this determinant is the main predictor of the adoption of technology. In the AIDUA framework, it is expected that a higher hedonic motivation by the consumer positively influences *Performance Expectancy* while a lower hedonic motivation negatively influences *Perceived Effort Expectancy*. Gursoy et al. (2019) derive the negativity from the low hedonic motivated customers perceiving performing tasks with AI devices to be difficult.
- Anthropomorphism: To the extent to which the AI device shows human-like characteristics. This could be connected to appearance, perceived emotions, and/or behaviour. The authors of the AIDUA framework state that the level of anthropomorphism influences both Performance Expectancy and Perceived Effort Expectancy.

When the customer has gone through the Primary Appraisal, they move on to the Secondary Appraisal stage. Here the decision-options and their consequences are considered by customers in terms of emotions, rather than purely logical. In the AIDUA framework, the formation of emotions towards the AI device is mainly driven by Perceived Effort Expectancy and Performance Expectancy. A positive evaluation made by the customer during the Primary Appraisal stage is weakened by a high Perceived Effort Expectancy and strengthened by a high Performance Expectancy, and vice versa. Gursoy et al. (2019) state that according to the Cognitive Dissonance Theory, first presented by Festinger (1962), when an object contradicts users' existing beliefs, it can lead to cognitive dissonance which causes discomfort. Continuing the author claims that customers therefore will try to lower the level of dissonance, by conforming rather than challenging their own beliefs. Therefore, users with a positive attitude during the Primary Appraisal stage tend to adhere to them rather than change (the same goes if people have negative attitudes, they tend to not change either). However, customers who believe that AI devices will result in improved service quality (or an increase in Performance Expectancy) will form positive emotions towards the AI Device, while increasing Perceived Effort Expectancy will have a negative impact on the formation of Emotions.

Lastly, according to what Gursoy et al. (2019) call "the complex appraisal processes", the formed emotions will be used in determining their willingness to either accept, or object to the use of AI devices. Gursoy et al. (2019) state that positively formed emotions during the secondary appraisal stage will make it more likely for the customer to accept the AI device in a service encounter. In contrast, a negatively formed emotion will lead to objection (in this case unwillingness) to use AI devices and instead wanting to rely on human interaction.

AIDUA - Moderating factors

Except for the mentioned experience moderating the effect that social influence has on Perceived Effort Expectancy and Performance Expectancy, the AIDUA model does not incorporate any other moderator as the ISTAM model. Thus, in an effort to incorporate moderating factors to take the models to a comparable fidelity and level, we looked to the Unified Theory of Acceptance and Use of Technology (UTAUT), developed by Venkatesh et al. (2003). The UTAUT does similarly to the AIDUA model have Performance Expectancy and Effort Expectancy as determinants of predicting technology acceptance. It also incorporates Social Influence and Facilitating Conditions as determinants of predicting technology acceptance and are described by Venkatesh et al. (2003) as followed:

- Social Influence: To the extent to which the users perceive it as important that other people believe that they should adopt the system. It is considered to have an effect on behavioural intentions.
- Facilitating Conditions: Apart from the three previous key determinants, facilitating conditions are argued to have a direct impact on the Use Behaviour. Facilitating conditions are to which extent the users perceive that the exists an organisation as well as technical infrastructure to act as support in the use of the system.

Despite being connected together in a slightly different way, we argue that the main moderating factors of the UTAUT model are Gender, Age, Experience, and Voluntariness to Use (Venkatesh et al., 2003) should be applicable to the AIDUA model. Therefore, by comparing the AIDUA and UTAUT models, we have incorporated the factors as follows into the AIDUA model:

- Voluntariness of Use: This is only thought to affect Social Influence. Venkatesh et al. highlights previous research that shows that users are dependent on other people's opinions to a significant degree, but only in a mandatory setting.
- Gender: Gender is seen affecting Performance Expectancy, Perceived Effort Expectancy, and Social Influence. Venkatesh et al. (2003) emphasize that the following predictions are based on cognitions associated with gender roles:
    - Performance Expectancy is expected to be higher among men. Venkatesh et al. (2003) highlight research pointing to men being more task-oriented than women and thus expecting more of the performance. However, they also highlight that it could be misleading to only look at the gender without considering their age. This as job-related factors may change for women between the time, they enter work and their parenting years.

    - Perceived Effort Expectancy is according to Venkatesh et al. (2003) more pronounced among women than men.
    - Social Influence is expected to be higher among women, as the Venkatesh et al. (2003) reference research concluding women are more receptive to others' opinions.
- Age: Similarly to gender, it affects the relationship between Performance Expectancy, Perceived Effort Expectancy, and Social Influence.
    - Performance Expectancy is expected higher among younger people (Venkatesh et al. 2003).
    - Perceived Effort Expectancy is expected to increase with age. Venkatesh et al. 2003) highlight research conducted that increased age makes it more difficult to process complex stimuli, as well as having difficulties in drawing attention to information presented to them.
    - Social Influence is expected to increase with age, as the Venkatesh et al. (2003) point out that the need for affiliation is higher among older people. Thus, it is assumable that older people are more dependent on social influences.
- Experience: This affects the relationship between Effort Expectancy and Social Influence.
    - It is to be expected that Perceived Effort Expectancy will eventually lower when the experience increases, as the initial barriers of adaptation have been overcome and overshadowed by other concerns.
    - Social Influence's effect on Performance Expectancy will decrease when users' experience increases, and they start to form their own perception of the use of the system.

The revised AIDUA model, incorporating these moderating factors, could be seen in Figure 7.

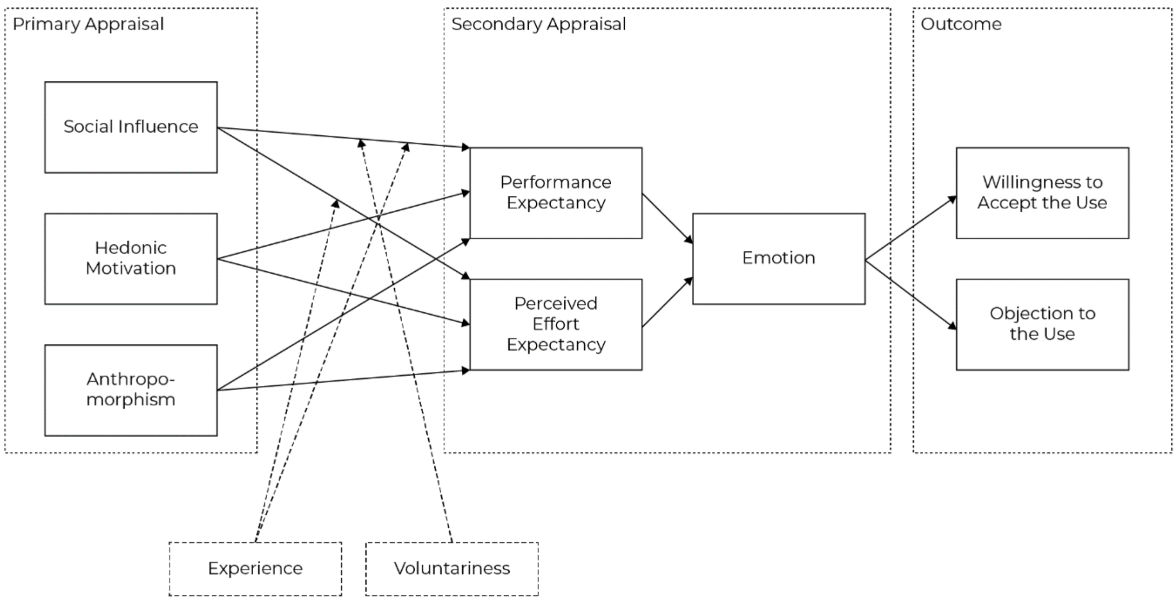

Figure 7 - Revised AIDUA model (redrawn from Gursoy et al., 2019).

Cultural Influence on Technology Acceptance

As brought up in the *Stakeholders – Interaction Diagram* section, there have been studies that suggest that people with different cultural backgrounds have different perceptions and different acceptance behaviours towards robots used in service delivery encounters (Chi et al., 2023). Despite multiple studies claiming the importance of culture in the acceptance of technology, Meng et al. (2009) argue that at least national culture cannot be seen to predict an individual's behaviour, as the culture cannot be fully homogenous throughout a specific culture. This claim is substantiated by Persson et al. (2021), who by comparing individuals' attitudes towards AI Systems, such as social robots, in Sweden and Japan (two very different cultures) found indications that there were greater differences between individuals within the country's population, rather than differences between them. Taking the previous statements into account, we suggest that culture should not be seen as a determinant in an acceptance model, but rather act as a moderator affecting certain relationships between the different determinants (like *Experience* in the previously presented frameworks). This contradicts Sunny et al. (2019) which previously tried to incorporate national culture into the first TAM as a determinant affecting Perceived Usefulness and Perceived Ease of Use, while conforming to others' research agreeing that cultural values should rather be seen as moderators (Metallo et al., 2022; Srite & Karahanna, 2006).

Subcultures

Continuing on the topic of culture, national culture has in multiple papers been defined as "values, norms, and practices that are undertaken by a country" (Ornelas et al., 2023). However, one criticism brought up by the paper *Redefining culture in cultural robotics* (Ornelas et al., 2023) is that by emphasizing national culture, you are missing those who have created their own identity within a larger group (referenced to as subcultures). Continuing, the authors of that paper state that it is therefore important to not only acknowledge national cultures but also that it exists subcultures that are more shaped through interactions between individuals. This once again makes things more complicated to study technology acceptance, as you then must reconsider how the individual may reshape its cultural preferences depending on the context the user exists in. However, to not make already complex frameworks too complex, we suggest that similar to other studies (Chi et al., 2023; Li et al., 2010; Lim et al., 2021; Sunny et al., 2019), you can view on the technology acceptance from the perspective of the national culture of something called *Hofstede's Cultural Dimensions*. However, with the previous reasoning, it is important to remain aware that the effect that these have on an individual may be greater or less in every situation and/or context.

Different Cultural Dimensions' Effect on Technology Acceptance

Hofstede introduced so-called Cultural Dimensions which could be used to compare and understand a national culture (Hofstede, 2011). The six dimensions that have been revised (multiple times) are according to Hofstede (2011):

- "Power Distance, related to the different solutions to the basic problem of human inequality" (Hofstede, 2011).
- "Uncertainty Avoidance, related to the level of stress in a society in the face of an unknown future" (Hofstede, 2011).
- "Individualism versus Collectivism, related to the integration of individuals into primary groups" (Hofstede, 2011).

- “Masculinity versus Femininity, related to the division of emotional roles between women and men” (Hofstede, 2011).
- “Long Term versus Short Term Orientation, related to the choice of focus for people's efforts: the future or the present and past” (Hofstede, 2011).
- “Indulgence versus Restraint, related to the gratification versus control of basic human desires related to enjoying life” (Hofstede, 2011).

So how do these factors relate to technology acceptance, and in what way? This question has tried to be answered by multiple researchers, among them being for example Srite & Karahanna (2006), Straub et al. (1997) and Zakour (2004).

- Power Distance: Based on previous literature, Zakour (2004) hypothesis that the Power Distance moderates the effect between the Subjective Norm due to people's tendency to comply with people higher up in the hierarchy. This is supported by Srite & Karahanna (2006) who highlight that people who are affected by a higher power distance are more likely to rely on and comply with the opinions of their superiors, as they are afraid to disagree (Srite & Karahanna, 2006).
- Uncertainty Avoidance: Srite & Karahanna (2006) claim that people in cultures with higher uncertainty avoidance have a tendency to seek answers and confirmation among their social group if the technology is to be adopted. Thus the hypothesis of the relationship between Subjective Norm and Behavioural Intention being moderated by Uncertainty Avoidance (Zakour, 2004) is substantiated.
- Individualism versus Collectivism: Srite & Karahanna (2006), as well as Zakour (2004) hypothesized that individualism and collectivism would have a moderating effect on the relationship between the Subjective Norm and Behavioural Intention. However, Srite & Karahanna (2006) concluded in their study that this did not have a significant moderating effect. This is somewhat contradicting to the results of the meta-analysis based on existing studies that Schepers & Wetzels (2007) performed. They did in fact conclude that it did have a moderating effect, but that it was stronger for more countries with a more individualistic norm than collectivistic. This was in contrast to their expectations as it was assumed that the people in a collectivistic culture would tend to conform to the social group (similar to the impact of Uncertainty Avoidance). This could have to do with the findings of Sunny et al. (2019), which found that individuals in collectivistic countries tend to care more about the group's success and are prepared to sacrifice their self-interests.
- Masculinity versus Femininity: In Srite's and Karahanna's study (2006), it was found that masculinity and femininity had an impact on the moderating effect on the relationship between Subjective Norms and Behavioural Intention. The reasoning is that individuals that are embracing feminine cultural values are more likely to be influenced by their social environment. This finding is further substantiated by the UTAUT (Venkatesh et al., 2003) who state that gender (in the form of gender role norms) had a significant moderating role on the effect of social influence on Behavioural Intention. Furthermore, Srite & Karahanna, (2006) have noted that this cultural dimension seems to have a moderating effect on the relationship between Perceived Ease of Use and Behavioural Intention, which is substantiated by (Venkatesh & Morris, 2000) who found that Perceived Ease of Use had a more noteworthy impact on Behavioural Intention among individuals conforming to the feminine gender norm.

For the last two cultural dimensions of Hofstede's model, there is not, to our knowledge, any academic research made on the specific moderating effect they have on the determinants in the TAM model (like the research presented just before here). This is due to the last two cultural dimensions being presented later (Hofstede, 2011). Nevertheless, we will try to explain from the existing literature how this may be related to the specific topic.

- Long Term versus Short Term Orientation: In a study performed by Chi et al. (2023) investigating the use of service robots (for different contexts, not only restaurants), the results suggested that cultures with long-term orientation are more likely to accept technology in a service encounter. This is the same conclusion that Veiga et al. (2001) came to, which further suggested that it affected Perceived Usefulness. It was suggested that people with short-term orientation want to see direct work benefits, which implies that it has a moderating effect on the Result Demonstrability as well as Output Quality. Furthermore, it could be seen to have a moderating effect on Job Relevance as Veiga et al. (2001) state that long-term orientated are more likely to take into consideration how the technology could be useful in the future work setting. This is further substantiated by Jan et al. (2022) who stated that it will be therefore important to help the employees understand the relevance of the technology and the impact that it would have in the future.
- Indulgence versus Restraint: In this literature review, no academic paper explicitly mentioned the effect that Indulgence versus Restraint has on technology acceptance. However, as this dimension relates to what degree the people within a culture seek enjoyment, it could be seen to have an impact on Hedonic Motivation's importance from a customer perspective and perceived enjoyment from the Employees' perspective. The higher indulgent people within a culture are considered, the greater the importance of incorporating hedonic motivation and perceived enjoyment into a design is.

The Swedish context

The question is how all this relates to creating a restaurant robot, which is to be accepted in the context of restaurants in Sweden. According to Hofstede Insights (2023), who ranks and provides a score on the different cultural dimensions for all countries, Sweden scores relatively low when it comes to long-term orientation as a nation. According to Chi et al. (2023) findings, this suggests a more reserved attitude towards any robot in service encounters. Sweden also scores relatively low when it comes to power distance, and high when it comes to Individualism (Hofstede Insights, 2023). This could affect the acceptance negatively since the Swedish employee might have a higher influence on the decision of implementing a robot while also valuing their job security higher than the benefit for the organization. In contrast to this, when comparing general robot acceptance at work, Turja & Oksanen (2019) highlights that Sweden ranked the highest among the European nations. Overall, this implies that there are mixed findings when it comes to general robot acceptance in Sweden and there is not an extensive amount of research done on specifically acceptance within the Swedish restaurant setting.

Walter et al. (2010) presented how different drivers affected the customer experience at different restaurants based on answers from Swedish customers. Two of the most frequent drivers that could be influenced by a restaurant robot were social interaction and core service. One key factor for a favourable experience was the empathy aspect of the service encounter and that situational understanding was a big part of this. Time and timing were also mentioned as important drivers for a favourable customer experience.

Andersson & Mossberg (2004) also conducted a study in Sweden where they investigated the driving factors for a satisfying restaurant experience. Their results showed that there were two main human needs to consider, physiological and psychological. Depending on which of these needs were predominant among the customers, different expectations of the restaurant experience could be found. Whereas they described it, high human touch establishments (such as full-service and fine dining) often catered more to the psychological needs of social interaction and low human touch establishments (such as quick service) mostly catered to the physiological need for food. They concluded that it is important to align both the aspirations of the restaurant and the customer expectations of the restaurant to create a satisfying experience.

This is in line with the findings of Della Corte et al. (2023) who stated that in low human touch establishments, a human service encounter might be less valuable for the customers, making it easier to accept the less personalized service of a restaurant robot. However, in a high human touch establishment where a higher service quality is expected, a restaurant robot might be more suitable for routine tasks rather than too much customer interaction.

Overall, many of the aspects involving the acceptance of restaurant robots are very context specific. Since there are so many different types of restaurants that operate in different ways, modularity in design might be an important consideration moving forward.

What Could Be Affected by Design?

As this thesis aims to create design guidelines for restaurant robots within the Swedish context, there is a need to understand more about certain factors and how these could be affected by the design. Considering all the factors influencing technology acceptance, from both a customer and employee standpoint, we recognize that not all can be directly addressed through design. Some factors are inherent to the individual users and while important to acknowledge, they are challenging to translate into design considerations. Among the factors suitable for design in our opinion after reviewing the literature, are Scandinavian Design, Hedonic Motivation (which is also associated with Perceived Enjoyment), Anthropomorphism, and Trust. While Trust emerged as a significant factor in the ISTAM model, we found the existing literature lacked comprehensive insights into its dynamics as it solely targets the concept of transparency. Furthermore, we chose to dig deeper into the concept of Function Allocation, as users' assessment of tasks depends on the restaurant robot's designated operations.

Scandinavian Design

The term Scandinavian design is ill-defined, but some key characteristics exist that make a product adhere to the Scandinavian design language. McFarley (2019) highlight that *form follows function* is one principle commonly associated with Scandinavian design and describes the practice of designing around the intended functions rather than aspiring for a certain appearance. This often results in a down-scaled appearance where every component serves a well-defined purpose. Norman (2023) further describes how Scandinavian design also commonly incorporates simple lines, warm neutral monochromatic colours, and avoiding cluttering to create harmony. The style is often associated with interior design but can be translated into various product categories.

As a member of Scandinavia, Swedish design is a part of composing the aspects mentioned above. The Swedish Institute (2024) highlights that an important aspect of Swedish design is the environmental focus as many Swedes have a close relationship with nature. This is often reflected in the use of organic, high-quality, sustainable materials and a transparent production process. The Scandinavian way of form follows function has also seen a change in recent years as more playful and colourful designs have started to trend amongst Swedish designers.

Function Allocation

When implementing some form of automation into a system, in this case, a restaurant robot, some of the previous functions performed by humans will be allocated to the robot itself. Wright et al. (2000) describes function allocation as a rational way of determining which functions should be allocated to either a human or automated agent. Hollnagel & Bye (2000) explains how function allocation can be divided into three main principles.

- The left-over principle where functions that for different reasons have not been automated are left for the human. According to Feigh & Pritchett (2014) this can result in an incoherent set of functions that potentially could be hard to coordinate.
- The compensatory principle where functions are allocated based on the strengths and weaknesses of both the human and the automated agent.
- The complementary principle where the allocation of functions is based on how the human and the automated agent can complement each other to achieve the goal.

Sharma et al. (2023) findings suggest that restaurant robots (the automated agent in this case) should not replace humans but rather complement each other. For example, combining the advantage of a robot being able to perform repetitive tasks with consistent quality, with the superior customer service provided by humans has the potential to enhance the overall customer experience. This finding could be viewed as in line with the third principle, *the complementary principle*, as most suitable for a restaurant service robot.

Feigh & Pritchett (2014) further elaborates and presents some general requirements for a successful function allocation. For example, the restaurant robot must be able to solve its assigned functions both separately but also as a combination of functions. When introducing automated functions, it is important to also consider additional human functions that are created and how that affects the overall workload. They continue by stating that when the restaurant robot in this case is implemented as a team member it is important that sufficient communication and understanding can be reached for an efficient workflow. Bergqvist & Rönström (2020) also found that an understanding of how a domestic robot worked and reasoned could in turn lead to the development of trust and willingness to use the robot.

Feigh & Pritchett (2014) also highlights that function allocation is very context specific and that it is difficult to generalize it for a wider range of contexts. Therefore, within the restaurant setting, function allocation will be important to consider as there most certainly are differences in functions between different establishments.

Anthropomorphism

Anthropomorphism can be described as the way that humans attribute human capacities to agents. In the field of robotics in general, anthropomorphism can be displayed in humanlike behaviour both mentally and physically through speech, body movement, facial expressions etc. (Waytz et al., 2010).

Fink (2012) emphasise that people are seeking similar ways to interact with agents as they would do with other humans which serves as an explanation for why people tend to anthropomorphize some agents. Epley et al. (2007) presented a psychological three-factor theory as to why people tend to anthropomorphize non-human agents.

1. When they have a mental model of the agent that they can relate to human behaviour.
2. When they need to create a mental model of an agent by relating its behaviour to human behaviour.
3. When they are in need of social contact.

Like the second factor in Epley et al.'s theory, Fink highlights research suggesting that in general people tend to have a better mental model of robots with a higher level of anthropomorphism.

When it comes to anthropomorphism's impact on the overall acceptance there are mixed findings. Della Corte et al. (2023) highlights that much of the previous research neglected the importance of culture, age, gender etc. when it comes to how anthropomorphism influences the human-robot interaction in service encounters.

Evers et al. (2008) found that Chinese people were more likely to anthropomorphize robots in general (which in this case is the agent) than people from the US and explained it by pointing out the differences in their main religious beliefs. However, Persson et al. (2021) found a strong correlation when comparing Japanese and Swedish people's views on anthropomorphism. Generally, both groups expressed similar positive effects that the anthropomorphism had on the human-robot interaction and the overall conclusion was that both had similar attitudes to the implementation of AI. DiSalvo & Gemperle (2003) concluded that the cultural aspect can have an impact on how well different efforts of anthropometric designs are perceived.

Złotowski et al. (2015) conclude that a well-designed system can generate a base for good human-robot interaction. They stress that a robot's ability to perform its task is more important than its appearance. However, anthropomorphism can help facilitate human-robot interaction by eliciting certain social cues and therefore increase the overall efficiency. At the same time, a higher level of anthropomorphism also increases the expectations of the interaction to adhere to human norms.

Similar to Złotowski et al., Blut et al. (2021) found that anthropomorphism had a strong positive effect on the human-robot interaction within service applications (e.g. in a restaurant context) as customers can apply social rules to mediate the interaction. Their research also highlights that intelligence, likeability, safety, and social presence are the key aspects where anthropomorphism can have an influence on future use intentions. Chiang et al. (2022) further elaborate on the service perspective stating that different levels of social interaction with a robot in general require different levels of automorphism. They exemplify this by stating that a meal-delivering robot with minimal Interaction requires a low level of anthropomorphism to achieve good service quality. They concluded that the level of anthropomorphism is very context specific and should vary depending on the types of tasks a robot is set to perform.

Ruiz-Equihua et al. (2022) goes even further and focuses specifically on the human-robot interaction within the restaurant setting. They investigate how the relationship between social cognition, psychological ownership, and anthropomorphism affects customer reactions. Social cognition was described as how humans evaluate social interactions focusing on warmth and competence. Psychological ownership refers to the phenomenon where people tend to generate a feeling of ownership as they invest time and effort in an agent, where attractiveness, receptiveness, and manipulability are some features of psychological ownership that could lead to better customer reaction. Their findings suggest that both social cognition and psychological ownership were crucial conditions for revisiting intentions whereas anthropomorphism served as an additional aspect to further improve customer reaction.

Although multiple studies have described anthropomorphism as a way to enhance various aspects of the human-robot interaction. Della Corte et al. (2023) also states that higher levels of anthropomorphism also increase the expectations of what a robot in service delivery encounters is capable of and that incoherence between the humanlike features and the level of intelligence can cause discomfort. This is further emphasized by Kok & Soh (2020) who highlighted that unnecessary loss of trust in robots, in general, can occur when the expectations of their capabilities are not met in reality. Therefore, they suggest that designers not only consider the physical appearance but also how it presents itself by being transparent in its capabilities.

Mori et al. (2012) presented the popular theory named the Uncanny Valley suggesting that as the level of anthropomorphism increases the affinity for a robot also increases to a certain level where some features of it suddenly become eerie and the affinity level drastically decreases to then excels as the robot resembles a healthy person (see Figure 8).

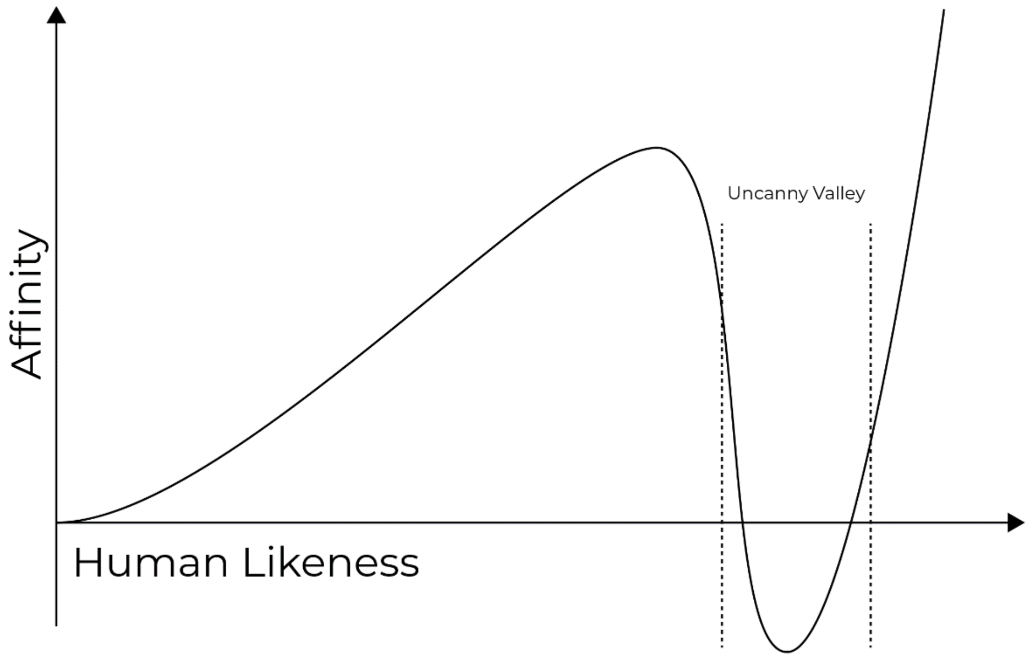

Figure 8 - Illustration of the concept of Uncanny Valley (redrawn from Mori et al., 2012).

As brought up by Zhang et al. (2020) there are multiple theories trying to explain why this phenomenon arises. However, they conclude by acknowledging an inconsistency within previous research. Złotowski et al. (2015) also highlights that the original uncanny valley theory has been questioned in multiple studies and other relations between anthropomorphism and likability have been suggested, although concluding that uncanny feelings and anthropomorphism are related. Murphy et al. (2017) address the service perspective and highlight that the short-term interactions between customers and restaurant robots do require a higher focus of the designers to prevent uncanny feelings since acceptance cannot be developed over time. More recently, Mori et al. (2012) added that designers should aim for the first peak of the affinity-human likeness graph and thereby be more deliberate when assigning anthropometric features to a robot in general.

Hedonic motivation

As highlighted in the AIDUA framework by Gursoy et al. (2019), hedonic motivation is a key determinant for the acceptance of new technologies. Lin et al. (2020) who studied the acceptance of AI-driven robots in the hospitality sector found that hedonic motivation had a direct impact on customer willingness to use the robots if they provided hedonic benefits. Continuing, Lin et al. (2020) attributed this to the customers with a higher degree of hedonic motivation who perceived that the robots exhibited a more reliable and precise service performance, necessitating less effort during use. Hedonic motivation has also been attributed to be specifically important in high human touch interactions (Della Corte et al., 2023), such as customer-employee encounters could be considered in a service encounter in restaurants (Blöcher & Alt, 2021). However, none of the mentioned authors in this paragraph dig deeper into what affects hedonic motivation and instead focus on the consequences of customers feeling joy and satisfaction.

To understand the driving forces behind hedonic motivation, you could study other fields that incorporate the hedonic determinant, one of them being Hassenzahl's (2018) UX model. Incorporating UX to further understand technology acceptance is not new as previous research has integrated the more experiential factors into existing technology acceptance models, and many of them are raising Hassenzahl's UX model (Hornbæk & Hertzum, 2017; Mahlke, 2008; Mlekus et al., 2020). According to Hassenzahl (2018) hedonic attributes should be differed from the pragmatic attributes, which are more instrumental/utilitarian and focus on fulfilling behavioural goals, such as the efficient use of tools for a specific task. Instead, the hedonic attributes should emphasize the user's well-being and pleasure. Continuing, the author states that hedonic attributes could be divided into three subcategories which are stimulation, identification, and evocation.

- Stimulation involves products providing new impressions, opportunities, and insights for personal development.
- Identification relates to the social aspect of expressing oneself through possessions and communicating identity to others.
- Evocation refers to products triggering memories of past events, relationships, or thoughts.

How to design restaurant robots remains unclear after reviewing the existing literature, and therefore more empirical studies are required to figure out what is expected from the end users. However, some implications could be drawn from the existing literature. First of all, the hedonic attributes could be measured and more easily understood with the help of a semantic differential scale called *AttrakDiff* (Bevan et al., 2016; Hassenzahl et al., 2003).

Secondly, positive hedonic experiences could be created in interactions between a guest-employee regardless of whether the restaurant robot is perceived as human-like or not (Della Corte et al., 2023). This distinction is further supported by the discrete distinction between the determinants of hedonic motivation and anthropomorphism in the AIDUA model (Gursoy et al., 2019; Lin et al., 2020). Furthermore, it is important to take into account the novelty effect that is created by introducing a restaurant robot (Koerten & Abbink, 2022).

Lastly, guests might feel the experience of interacting with a robot to be enjoyable and give them satisfaction because it is something new (Belanche et al., 2020; Sharma et al., 2023). This is substantiated by Seyitoğlu et al. (2021), who argue that robots could, and are used as more of a marketing tool and a way of creating competitive advantages. However, Zemke et al. (2020)

highlight past examples of the integration of restaurant robots and point to customers visiting the restaurant once for the sake of the experience, but not returning due to the poor service quality in the end. Therefore, it is essential to understand which, how and the embodiments of the tasks create meaning for the users over time (Karapanos et al., 2009) to maintain the user experience and be a future-proof investment for the organizations it operates in.

Trust

Several studies have found that trust is a central topic within the field of human-robot interaction (Kok & Soh, 2020; Law et al., 2021; Natarajan & Gombolay, 2020), and that it is important to create preconditions for an appropriate level of trust to enable them to be around a social environment (Kok & Soh, 2020), such as a restaurant robot. Trust has been suggested to have a direct impact on performance expectations as well as effort expectancy by customers for interactions with robots in general (Della Corte et al., 2023). Integrating trust into a restaurant robot presents significant challenges because trust and technology acceptance in human-robot interactions are complex and difficult to clearly define and measure (Vorm & Combs, 2022). Trust could also be difficult to design for in certain situations, as trust in a robot dynamically changes over time (Kok & Soh, 2020)

But before taking a deeper look at the concept of trust, it is important to define what trust is. A user's trust in a robot in general could be seen as a property of the relationship between the two actors (Kok & Soh, 2020). Hereafter we will go on with the definition of trust provided by Lee & See (2004), cited as "*trust can be defined as the attitude that an agent will help achieve an individual's goals in a situation characterized by uncertainty and vulnerability.*". Kelly et al. (2023) supports this definition by stating that trust in technology can be seen as a user's belief that the device (agent) will provide help in achieving one's goal. Furthermore, Kelly et al. (2023) give an example of the concept of trust, by describing it as one user's belief that GPS will provide the correct direction to successfully arrive at a certain location. Important to highlight is that trust should not be confused with the term trustworthiness. Instead, trustworthiness should be seen as a property (in the case of technology acceptance) of the agent, in this case, a robot (Kok & Soh, 2020).

Looking at the presented definition of trust, the situation in which trust should be created must contain some degree of uncertainty and vulnerability. Therefore one important component moderating how much trust influences the acceptance of a restaurant robot is the *perceived risk* in the context of interaction (Chen et al., 2020). This has been studied in the use of restaurant robots and substantiated that perceived risk is a driving factor in how much trust needs to be integrated (Della Corte et al., 2023; Seo & Lee, 2021). Continuing, they state that increased trust in a robot, in general, will lead to less perceived risk in a situation. For example, in the field of Robotic vacuum cleaners, the perceived risk is lower due to its small size, and allocating resources to incorporate trust is not seen as important (Bergqvist & Rönström, 2020). In contrast, in autonomous vehicles, perceived risks are higher due to for example fear of hurting yourself, pedestrians, etc. (Ekman, 2023), making trust more essential. However, perceived risks do not only cover situations that may cause harm in any way (material or personal damage). In the context of restaurant robots, fear could be related to losing service quality and/or other failures during service (Della Corte et al., 2023). There are also findings suggesting that a higher reliability among automated systems, such as a restaurant robot could be considered, leading to a higher degree of trust (Baker et al., 2018). This implies that the restaurant robot needs to be considered high in its reliability with a low error frequency. The concept of higher reliability is substantiated by Złotowski et al. (2015), stating that for people it is more important that the restaurant robot does its job accurately and with a higher output quality, rather than for example its appearance.

However, appearance should not be neglected. To design a restaurant robot that could enable trust in human-robot interactions, one could work with the physical appearance, as decisions made to trust often are stronger at first impressions (Kok & Soh, 2020). This claim is also substantiated by Bergqvist & Rönström (2020) who points out that issues at the beginning of a human-robot interaction have a strong impact on trust. However, it is essential to be aware that only changing the appearance (not manipulating other aspects accordingly) may lead to over-trust (Schreiter et al., 2022). Matching the appearance to the function can therefore be seen as essential. Furthermore, it should be noted that trust could also be moderated by other cues than its physical appearance, such as movement and audio (Law et al., 2021).

As Kok & Soh (2020) stated in their study, by only working with appearance you target the perceived trustworthiness of a robot, but when the robot is presented as is people tend to overestimate what it can do. The mismatch, what Kok & Soh (2020) called the expectation gap, which leads to a loss of trust after the actual use of the robot. When the trust matches the robot's capabilities, it could be considered calibrated trust which in turn leads to appropriate use (Lee & See, 2004). This is what could be considered an *appropriate level of trust*. In contrast, is the concept of miscalibration which will lead to over trust, leading to misuse, or distrust which will lead to users not wanting to use and adopt the system (Lee & See, 2004). Here is where the previously defined concept of transparency could be considered one key element to foster a properly calibrated interaction and lead to a higher perceived trust (Baker et al., 2018). Users would benefit from a more accurate perception of a robot's capabilities and intention of use in a given situation (Lyons, 2013). Transparency also has a great impact in case of failures during its operation. Della Corte et al. (2023) explain this by stating that individuals who can't figure out why something went wrong will feel a loss of control and authority, thus lowering the level of trust they put in a robot. Continuing on the topic of understanding robot's capabilities, it could be even more important for users without any specialist training that with limited understanding may cause miscalibration in the form of over trust (Ekman, 2023). In the field of autonomous vehicles, the term *authonwashing* has been coined to describe situations where the gap between the actual capabilities and the portrayed capabilities by the developers/manufacturers (Dixon, 2020).

Lastly, it is also important to consider that culture has an impact on trust (Hoff & Bashir, 2015), as well as more specifically how you should repair it (Baker et al., 2018). Culture could impact specific features of a robot, such as its appearance, as well as behavioural features, such as the communication style (Baker et al., 2018). As earlier described, culture could be difficult to describe and assign to the users. However, if the robot can conform to a few culturally appropriate norms, it is more likely to be integrated (Baker et al., 2018). In addition, as Vorm & Combs (2022) do also highlight that even though culture is difficult to define, designers should maintain awareness of this when working with trust.

3.3 Conclusion

To conclude this literature view, some key takeaways are presented.

- From the employees' perspective, the acceptance of restaurant robots could be studied with the help of the ISTAM model. The main determinants that directly influence the

Actual Use are Transparency (trust), Perceived Usefulness, and Perceived Ease of Use. However, there are other factors as described subsequently having an impact on these.

- From the customers' perspective, the acceptance of the restaurant robots could be studied with the help of the AIDUA model. The main determinant affecting the rejection or adoption of technology is Emotion, which is determined by Perceived Effort Expectancy, and Performance Expectancy. These are affected by Hedonic Motivation, Anthropomorphism, and Social Influence.
- Both the customers' and employee's acceptance of a restaurant robot are affected by experience as well as voluntariness of use.
- Not all design considerations could be accounted to one specific determinant, or in certain cases any. These models should be used as a guide when making certain decisions to create acceptance for a restaurant robot (an example of this could be design decisions due to the environment and regulations rather than to an individual user).
- Culture is difficult to define, and previous research shows that the individual differences within a country might be more significant than when comparing different countries. Overall, when generalizing the whole nation, there are mixed findings when it comes to restaurant robot acceptance in Sweden. However, following a few culturally appropriate norms within the nation might result in higher acceptance. For example, by following Scandinavian design values.
- There is not a clear definition of Scandinavian design, however, *form follows function* seems to be a common theme.
- Anthropomorphic features could be used to facilitate interactions between the users and the restaurant robots. However, the functional expectations that come with more human-like features should match to avoid uncanny feelings. In other words, there should be a coherence between the restaurant robots' functions and their appearance.
- Today robots in general are mainly used as a marketing tool, and the long-term effects are somewhat unpredictable when the initial hedonic motivation disappears. A high awareness when evaluating design proposals should be taken and try to differentiate what is more likely to be accepted over time, and what is accepted short term due to the novelty aspect of it.
- Due to the above-mentioned effect experience has on hedonic motivation (and perceived enjoyment), as well as other determinants, studying technology acceptance can be regarded as time sensitive.
- The perceived level of intelligence of the restaurant robot by the user, will affect how much trust is needed to be created between the user and the robot. This refers to the concept of calibrated trust, in which appropriate use is created.
- Lastly as a conclusion, the restaurant robot must adapt to the context in which it is placed, whether the restaurant is perceived as having a high human touch (often associated with the fine dining segment) or a low human touch (often associated with the quick service segment). This implies that customizability will be an important consideration. It should also be emphasized that some restaurants are unlikely to be suitable for integrating robots.

4
User Research

This chapter outlines how the user research was performed and its corresponding data analysed, as well as the main results from each activity. It concludes with a short summary of the main findings which led to the narrowing of the scope of the master thesis.

4.1 Procedure

In this section, how the data was collected is described, as well as how the data was synthesized into insights into users' needs and requirements.

4.1.1 User Interviews

To get a further understanding of robot acceptance in Sweden, a total of 22 semi-structured interviews were conducted with different users. The interviewees were divided into three different categories, *dining customers* (from here on only will be referred to as *customers*), *employees without robot experience,* and *employees with robot experience*. With this, the aim was to capture the expectations of the employees without robot experience, and the actual experiences of the employees who had previously or are currently working with restaurant robots. The interview questions were mainly based on the ISTAM model (for employees) and the AIDUA model (for customers), and therefore mainly concerned the topics of perceived usefulness, perceived ease of use, trust, performance expectancy, and perceived effort expectancy. Additional questions related to the conclusion of the literature review were incorporated, such as questions targeted to understand how users perceive the context of restaurants. The questions were noted in an interview guide (which can be seen in

Appendix B – Interview Questions), that was used during the interviews. To confirm that the questions were easily understood, three separate pilot interviews were conducted.

The recruitment of participants was conducted using social media platforms, personal network contacts, as well as targeted emails/phone calls, with the goal of getting a broad range of participants. This resulted in qualitative data that could be used to analyse the driving factors for robot acceptance from different users' perspectives.

Table 1 - Age distribution of the different groups of interviewees.

Age	Customers	Employees with Robot Experience	Employees without Robot Experience
20-29	4	1	3
30-39	2	4	1
40-49	0	0	0
50-59	2	2	0
60+	3	0	0

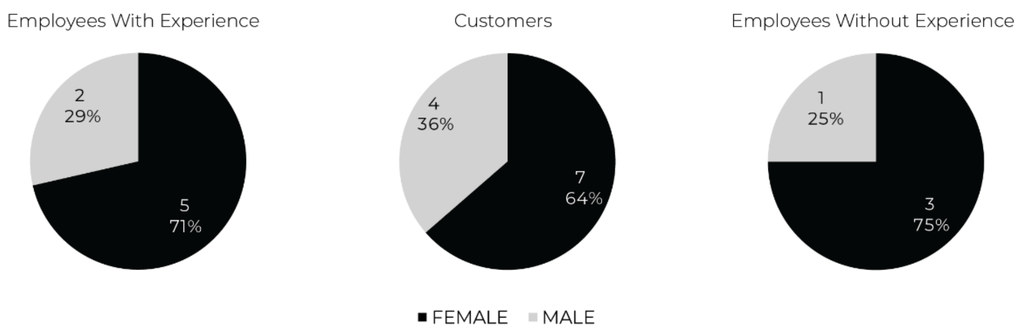

Figure 9 - Gender distribution of the different groups of interviewees.

Note On GDPR Considerations

All the data collection was performed, and stored, in an ethical way that conforms with the GDPR Regulations. At the beginning of the master thesis, we agreed in consent with the cooperating industry partner, to follow Chalmers' framework for data processing. Thus, before the user interviews, the checklist in the article "Handling of Personal Data" published on Chalmers' website (Chalmers University of Technology, 2023a), was gone through and studied in detail to ensure that the data collection would be conducted the correct way.

4.1.2 KJ Analysis

A KJ analysis was used to systematically analyse the data from the interviews and find patterns among users' needs and requirements. The interviews which had been recorded, were transcribed, and reviewed to extract citations that could be placed in virtual Post-it notes in a digital collaborative workspace. To enable identification of its origin, excerpts from all interviews were assigned a shade of a specific colour corresponding, to three interview categories (customers, employees with robot experience, and employees without robot experience). This also provided an overview of what type of user most citations originated from within each theme.

All excerpts were then reviewed and, through a thematic analysis, grouped to create a first iteration of themes. During this process, excerpts deemed irrelevant to user acceptance of robots were removed from the analysis. Subsequently, the identified themes were further refined, resulting in the establishment of 57 distinct thematic categories, e.g. movement, ease of use, and cleaning.

In order to more easily keep track of where citations originated from, the Post-it notes were divided into three color themes (one for customers, one for employees with experience of using robots, and one for employees without experience of using robots). This also provided an overview of what type of user most citations originated from within each theme.

4.1.3 Observations

To get insights into how existing robots on the market were being used by intended users in real-life situations, observations were determined to be executed. The observations were done in an unstructured and naturalistic manner, meaning that the observations were done without any interventions to minimize the observer's impact on the behaviour of the users.

The same restaurant was observed on three separate occasions. These were two breakfast servings (with both a la carte and buffet) as well as one lunch serving. Both employee and customer interactions with the robot were classified, and their frequency of occurrence was noted in a spreadsheet. In addition, notes were made when interactions occurred that were deemed extra interesting.

The insights from each observation session were summarized as a base for discussion. Due to the robot being sparsely used the amount of information gathered throughout the observations was limited resulting in no further analysis being needed.

4.2 Results

The interviews and observations provided qualitative data, contributing to an understanding of the acceptance of restaurant robots. Due to the volume of insights from the analysis, not all are included.

4.2.1 Insights - User Interviews

In general, it could be stated that it is challenging to create widespread robot acceptance for both customers and employees due to being heavily dependent on the context in which it will operate (this was also suggested by the literature review). The findings also suggested that there are conflicting attitudes not just between the different user groups but also within a group of users.

There were also factors brought up that would be impossible to overcome with the design of the robot, as the basis for creating acceptance would not exist from the beginning. One prominent example that was brought up in the interviews, was the fear of job losses if a restaurant visit was to be fully automated. From the employees' perspective, they questioned the relevance of their jobs if robots would take over certain tasks. Meanwhile, customers expressed a preference for supporting restaurants and their employees who have chosen not to automate any part of their operations with robots, feeling compassion for those who might lose their jobs otherwise.

However, the following are the most influential insights into the needs and requirements of customers and employees, which could be translated into, and had the greatest impact on the final design guidelines.

Service Centred Around Humans

In the interviews, it was noted that both customers and employees valued that the service in restaurants is being (or is perceived as being) centred around a human. Customers mainly attributed this to what can be best described as *the human touch* of the employees. As mentioned in the section *1.5 Restaurant Segmentation*, this can be described as a sort of situational awareness by humans regarding for example the ability to read people’s emotions, timing, and other implicit knowledge that comes with life and work experience. The expected level of human touch in a service interaction was higher the more “fancy” you perceived the restaurant. In the interviews with customers, it was agreed among every interviewee that the level of service they would expect from a quick-service restaurant (a context which is perceived to have a low level of human touch) would be significantly less, and therefore would not be minded being served their food by a robot. In contrast, employees who worked closer to the fine dining segment expressed the difficulties of implementing a robot at their restaurant since their customers expected a very professional and personalized service. One of the best examples of when the human touch was valued as highest, would be when ordering food. During the interviews, it became apparent that despite the technological feasibility of ordering via the robot, e.g. through an attached display, neither employees nor customers would appreciate it elsewhere than in a quick-service restaurant. Customers stated in other contexts or situations than when they wanted the food quickly, they wanted to be able to interact with the employee and ask questions about the menu and possible wine pairings, ask about what the food contains (for special preferences such as allergies), etc. Human touch is also valued highly among employees, as this is a skill they value being good at.

Continuing on this topic, customers expressed that they would expect to pay less when visiting restaurants that have implemented a restaurant robot. This is due to them associating robots with automation and consequently a way of cutting costs. Therefore, they would expect to get a "discount" by paying less, believing the restaurant has compromised on some aspect of its service. However, it is quite possible that the restaurant introduced the robot as a working tool, which actually increased its costs. This pointed to the general opinion among customers who believed that a robot could not provide any feel of human touch.

In the end, all of this points to the need for both employees and customers to be able to interact with each other to feel like any part of the service has not been sacrificed for the benefit of the robot.

Anthropomorphism

At one point during the interviews with customers, they were presented with pictures of robots that are marketed to be used in restaurants, ranging from having no anthropomorphic to very anthropomorphic physical appearance (humanoid). Those with none to a low number of anthropomorphic features were seen as having fewer functions and thereby not being useful, as well as unsuitable in any other restaurant context than in a fast-food establishment as it would not fit into “feeling” of the other restaurant segments. Some customers attributed those robots to be “an expensive automatic tray cart”. In contrast, the robots with the most anthropomorphic features were commonly seen as eerie and unfitting in a restaurant context in general. However, most customers agreed that there should be some form of anthropomorphic features but highlighted that these should fulfil a function.

During the interviews, both with customers and employees, a common phenomenon was detected of having a mental model of what a robot is based on pop culture that the person in question has consumed (such as from movies or other media). This was seen to have a great impact on users' preconceived image of robots in general, and acting as a foundation if they are ready to accept robots or not. Those who have seen dystopian movies about robots taking over the world were more sceptical than those who watched family-friendly movies where the robot helps to save humanity. All these insights pointed to the need to find an appropriate level of anthropomorphism for the robot, both regarding appearance and behaviour.

Robots' Perceived Usefulness

There was a difference regarding the expected and experienced capabilities of a restaurant robot. Employees without robot experience had in many cases an over-belief in the robots' capabilities, making them disappointed when they found out what they were limited to. There was then a consensus regarding the perceived usefulness of robots to be relatively low. No full-service restaurant was comfortable using a robot to manage service encounters since they believed that it would negatively affect the service quality, and did not see what it could contribute to, without sacrificing any part of the service.

One key aspect regarding the robot's usefulness, as highlighted by employees with experience using robots in restaurants, was that the robot was not utilized as intended during busy periods in the restaurant. This was due to many reasons. Firstly, it could not move as intended as it constantly had to stop on its path to avoid people. Secondly, it was difficult to anticipate when the robot was going to be available the next time, making it difficult to plan to send out orders. Lastly, when the employees felt stressed, they would feel like the robot added an extra workload of having to put things on the trays, and in combination with having to plan when it was free made it feel easier to just carry out the items by themselves.

However, when asked if these problems would not exist, and if the robot could be used as a complementary tool many were positive confirming there was an underlying problem with the repetitive task involving heavy lifting. Similarly to the employees, no customer was opposed to automation in this aspect within a full-service restaurant. Many customers could also see the benefits of robot implantation when it came to minimizing heavy lifting for the employees, as well as more and better service opportunities for the employees by being more present in the room (without having to constantly run back and forth to the kitchen). From the customers' perspectives, one of the most beneficial things a robot would be able to provide is getting the food at the same time. This was highlighted as a thing that provided something extra to a restaurant visit and was valued highly in the service. The robot being able to carry more plates than a human was therefore seen as essential by the customers.

Trust

Generally, both customers and employees did not express any concerns about them being in the same room as a robot. They all expressed confidence in the robot being able to avoid collisions, thereby putting trust in the technology of the robot itself (at least regarding movement/navigation). However, whether they are based on the trust of the robot itself, or rather the existing laws regulating what could be released onto the market remains unclear.

Nevertheless, it was also expressed that this trust would be hurt in case of an incident such as that of a collision. They would assume that something within the robot (e.g. the lidar sensor) would be broken, even though it would be impossible to hinder (e.g. if someone walked very abruptly in the robot's path, making it physically impossible to break in time). Therefore, feedback on the reason behind the incident and/or failure would be greatly appreciated among employees, who then could determine if they had to take action to prevent similar incidents.

Throughout the interviews (both with customers and employees), a reoccurring concern partly in relation to trust was how the robot would manage food preferences. These inquiries varied from specific requests to remove ingredients due to individual dislikes, accommodating dietary restrictions such as vegetarianism, to addressing severe food allergies. This was one strong reason for customers also not wanting to order through for example voice commands (other than wanting the social aspects of a human interaction), as they were afraid it would mess orders up and thereby not trust it. One other question was that if the plates were not marked with which order was which, they could easily be mixed up if a server was not present.

Lastly, another point raised regarding trust, when interviewing employees from the cheaper part of the full-service restaurant segment, was the trust they placed in their guests. These employees meant it would work better in a less crowded more controlled setting such as fine dining where a certain behaviour was expected from the customers. Two participants expressed that they would not trust their guests to behave around the robot and believed that guests would steal food or beverages from the robot if it was left completely unsupervised. This is somewhat contradictory to customers who, as has been previously highlighted, only would like to be served by a robot in a quick-service restaurant.

Ease of Use

Similarly, to having technology that worked reliably throughout the whole day, customers and employees stressed the fact of having technology that was easy to use. Technology that does not follow the convention of how it should work or is overly complicated with too many steps, resulting in prolonged task completion, would create an unpleasant and frustrating experience. A few customers even went as far as to say if any part of the visit generated these frustrating feelings due to technology (like ordering through a display, QR code or even reserving a table online), they would change restaurant immediately. Employees talked about technology being easy to use to not cause any stress, especially during the busier hours of the restaurant. Those who had experience of working with robots stated that this was an aspect of the robot they particularly liked, as today's robot required minimal training and often followed the convention of how their smartphone (or similar smart devices) worked.

During the interviews (with employees experienced of working with restaurant robots), it was asked about how the work had been adapted with the introduction of robots. They stated that not much had changed, which they saw as something positive as the barrier and learning curve was not seen as a problem. Therefore, it could be seen as beneficial to make the robot fit in with the employees' existing ways of working.

Movement

In the interviews, both customers and employees were asked how they expected the robot to move and behave in an encounter. Many of the interviewees mentioned that the most beneficial would be if it behaved like a human (anthropomorphic). However, when asked to further explain what they believed moving like a human meant, they started to explain but rather quickly realized that it was an intricate interaction and difficult to explain as this is done subconsciously.

Furthermore, everyone agreed that the most important thing was that it should be clear to everyone what the next action of the robot should be and that there is very little room for confusion. There were on the other end different opinions regarding whether the robot should adapt to the actions of the human, or if the human should adapt to the robot. Some of the interviewees stated that they would prefer the robot would take the command and perform its action early to not create confusion. On the opposite, there were interviewees who wanted the robot to always stop, or move very slowly, when meeting a human, and wait in its position until the human passed safely.

One repeating question that was brought up during the interviews, mainly from employees, but also a few customers, was what was going to happen if the robot faced any obstacle on its way. Examples as a chair was pulled out too far, or a jacket that had been dropped on the floor. This was not uncommon according to the interviewees, and some thought this would induce stress due to having to constantly check for these types of obstacles. They called for the need for the robot to either be able to call for help to fix the issue or be able to quickly identify that it is an obstacle in its path and take another route to the designated destination.

In relation to movement, employees emphasized the crucial need to promptly serve hot food to customers. One interviewee elaborated by explaining how they were adapting their actions based on whether they were carrying freshly cooked meals or dirty dishes. In the first scenario they would be required to move more determined, prioritizing arriving at the table more quickly, rather than letting customers through, while in the second scenario, they would let customers pass first to be more polite. The robot's ability to move swiftly throughout the restaurants, as well as not stopping all the time for passing customers, was therefore lifted as a concern.

Lastly, regarding movement, it was also mentioned as crucial for the robot to have some indication by sound while driving around, for accessibility reasons (for people who are for example visually impaired). They did however wish that it would be more adaptable being a distraction for customers while enjoying the meal.

Hedonic Motivation

Since none of the customers that were interviewed had first-hand experience with a restaurant robot, there was an underlying interest founded in curiosity about the technology. Many were intrigued to visit a restaurant using robots, but they clearly stated that the initial hedonic motivation would wear off quite quickly if a sufficient level of service could not be reached as they already were sceptical. This was a factor that many restaurants took advantage of, as in a few interviews with employees experienced working with restaurant robots, they stated that one key factor of the decision to acquire the robot was due to marketing reasons. Continuing on their statement, it created a buzz around the restaurant, and they noticed that some of the guests were visiting exclusively to have the opportunity to be served by the robot. Mainly it was among the younger audience (kids) that it was mostly appreciated, but however, it was pointed out that it also was a few adults being interested in the technology. The restaurants all stated that the interest in the robot had not gone down significantly, despite having it implemented a while ago, and that they still received questions and saw guests taking pictures of the robot. However, they also stated that they all were very selective in what type of customers they sent the robot to since they had noted that some people would not appreciate that type of service in their restaurant.

One feature that has been commonly used in existing restaurant robots to make them more anthropomorphic, as well as to create a higher level of hedonic motivation, is the use of a face that can make different facial expressions through a display. This is greatly appreciated especially by the younger users (kids) but the employees with longer experience of using robots have noticed that it is not without negative consequences. They explained that they had noticed that people perform actions to trigger the robot to show emotion, thus hindering it from performing its intended tasks. The clearest example is standing in its path to make the robot cry and say sad comments, which is found amusing amongst some guests. It was agreed among many of the users that the way the robot communicated was fun, but that it should not be intrusive. This included many things some of which were a squeaky voice (which a user referred to as "kawaii” from Japanese culture), having it repeat itself (this drove the employees crazy), or generally being too loud driving around.

A more general notion on the topic of restaurant visits, many of the interviewed customers noted that they often visited restaurants for the sake of having a new experience. This is why many of the employees highlighted the importance of creating a profile (style) of the restaurant that differentiated them from the rest. To do this it often involved creating harmony between the food, interior, working clothes, etc., implying that the robot itself should be able to adapt to the profile of the restaurant.

Lastly as mentioned by almost every employee, interacting, and socializing with customers are by them seen as the source of hedonic motivation in their jobs. They highlighted that this aspect of their work allows them to form personal connections, and have meaningful conversations, and often they receive immediate feedback and appreciation from customers, which is seen as highly rewarding and what makes their jobs fun.

4.2.2 Insights – Observations

The robot (in the restaurant in which the observations were performed) had a set operating area that covered about half of the restaurant. This had to do with obstacles such as rugs and other furniture in the second half of the restaurant, which the robot could not handle due to technical reasons. Within the area of operation, the robot had two base positions, one in the kitchen and one at the opposite end of the restaurant. Important to notice, is that the observations took place during a restaurant’s initial phases of robot introduction, as employees were still learning how to use it efficiently.

In general, it could be said that the robot was used very sparsely by the employees during all three observations. On multiple occasions, employees could be seen carrying dishes, rather than putting them on the robot despite it standing next to them and waiting for an assignment. This showcased that for some reason many employees did not bother to utilize the robot even at times when it was easily accessible to them. It is however hard to speculate on the reason for this behaviour. One explanation may be that employees felt the need to walk into the dishing area regardless (to unload it in the kitchen). Instead of dealing with the extra steps and waiting time involved in loading and unloading the robot, they choose to carry the dishes to the dish area manually. This could also have been the result of inexperience or lack of training, but it also showcases the importance of considering the robot to be a part of a network of multiple entities (both tangible and intangible) that should work together in tandem (e.g. the robot itself, the employees, the restaurants’ way of working), and not only exist as a single entity, which may require additional devices, new routines, and infrastructural changes, etc.

During breakfast servings, it was observed that the robot had a set route where it went to every table to collect dishes. At some times this became very repetitive as the robot approached the same group of guests within a very short time span. This appeared to cause some frustration amongst a few guests, as it forced interactions where there might have been little to no need for dishes to be collected. There were also multiple situations where the customer appeared to be confused about how to interact with the robot. This could be due to its poor clues on what to do during an interaction, e.g. it had a set delay of how long a robot should stay at each stop unless someone actively pressed a button on the screen to dismiss it. However, as the interactive screen was positioned at a height and angle that made it difficult to reach and see from lower tables, this was often missed. This showcased the importance of clear feedback and clarity of both content and placement of interactive features.

These observations do not completely reflect the entire spectra of service interactions. However, most of the problems with the robot appeared to be systematic rather than related to specific functions. Therefore, it is important that the robot can easily be adaptable to multiple different systems and scenarios of usage.

4.3 Conclusion

As a part of the user research, both user interviews and observations were performed to get insights into users' needs and requirements. The most important user insights were related to the themes, service centred around humans, anthropomorphism, robots' perceived usefulness, trust, ease of use, movement, and hedonic motivation. From the observations, it could be seen that the robot was ignored and not used as intended. It can be concluded that this could either have to do with inexperience (as the observations were performed at a restaurant which was in the early phase of adopting a robot), but also that the robot is not part of a network of multiple entities, and thus its implementation causes suboptimization (the processes are inefficient and ineffective). Furthermore, it could be seen that clear feedback and placement of interactive elements are essential.

The rest of this conclusion will present how all these insights "forced" us to narrow down the scope in which the robot should operate and ended in a first draft of design guidelines.

Narrowing Down the Scope

Since the expected level of service by customers differed greatly between the different restaurant segments, and the indications acceptance for a restaurant robot would not be possible in all different restaurant types i.e. fine dining, quick service, and full-service, it was decided to narrow down the scope in the continuation of work. The following statements are some of the rationalizations made to converge to the full-service segment.

Quick-service restaurants, such as fast-food chains, despite having a limited level of service, showed to be a less than favourable context to implement a robot. For example, one major factor was the robot's poor ability to move around in crowded environments, as it would constantly be required to stop due to safety distances. This would not be suitable for the often fast-paced and busy environment often associated with quick-service restaurants. Another aspect is that it would be difficult to motivate the implementation of a restaurant robot due to the associated costs that would most probably increase the price of the provided service. Today, most quick-service restaurants depend on self-service solutions to minimize costs, and as their customers primarily aim to fulfil their basic need for food, and not the service and enjoyment, they would not experience an increase in value being served by a robot. Furthermore, numerous major franchises have already established specialized, efficient systems to streamline their operations. For instance, they have introduced options like ordering food via a display and picking it up at a designated location. This was already considered sufficient by customers, who despite the availability of table delivery options today, often opted not to choose them.

For the fine dining segment, neither customers nor employees would currently accept the implementation of a restaurant robot. Customers stated that when they visit these types of restaurants, they liked being treated a bit extra by the employees, by for example being presented with the food and associated drinks, and they did not believe that a robot would have a possibility to do that. They also stated that a robot would not fit into the general feeling and atmosphere of visiting a fine dining restaurant. For employees, they did not see the usefulness of it, as it is often smaller companies at this type of restaurant. They did also, similarly to the customers, feel like it would not fit into the general profile of the restaurants associated with the segment. In addition, there seemed to exist a reluctance to add too much technology, as they were afraid of what would happen if something broke down. All this was pointing to a general negative attitude that would be difficult to convert, at least until those robots have been proven to be useful in providing good service in other segments.

Therefore, this project converged into focusing on the remaining full-service segment (which can be seen as a middle ground between the previous two). There is a level of expected service from the customers, but not as crowded and often not as fast-paced. Secondly, employees could see the usefulness of it in assisting in carrying plates and dishes as there could more often be larger companies and more food needing to be delivered simultaneously.

First Draft of Design Guidelines

All the insights were translated into a first draft of design guidelines, which would be in focus for further refinement during the next phase of the master thesis. These guidelines were divided into four different categories: *Appearance, Function, Interaction*, and *Desired Result of Implementation*.

- Appearance: These guidelines are supposed to target the purely visual aspects of the robot.
- Function: These guidelines are supposed to target the functional aspect of the robot, and not the interactions specifically between the robot and human.
- Interaction: These guidelines explicitly target the interplay between human and robot, and aid in developing a good functioning interaction.
- Desired Result of Implementation: As the name suggests, these guidelines are supposed to act as confirmation when validating the designs.

In addition to these categories, it was specified with each guideline who it affected, as well as documented where it originated from (for easier backtracking during the refinement process).

5
Designing and Refining

This chapter describes the process of applying the design guidelines in practice, which was done with the aim of refining them. The final design guidelines are then presented alongside the resulting design concept of the robot, serving as an example of their potential application. Finally, the chapter concludes with a summary of the implications of this process.

5.1 Procedure

This section outlines the various design activities that were done in order to refine the design guidelines, alongside the development of a design concept that could illustrate how these guidelines could be applied in practice.

5.1.1 HTA

After deciding where the best possible application area of the restaurant robot would be in the current situation (see *4.3 Conclusion*), a HTA was conducted. This was done by creating a hierarchical structure diagram, describing a flow of tasks generally involved within a full-service restaurant setting. These tasks were derived from the interviews in the user research, where employees (both with and without experience) were asked to specify the different steps and actions taken during a typical customer journey. As the precise tasks could differ between restaurants, the resulting HTA does not reflect one specific restaurant. Rather it was aimed to describe the tasks generally involved.

Based on the insights gained from the interviews and observations, the different tasks in the HTA were color-coded based on the predicted acceptance if the task would be allocated to a robot. A green task represented acceptance, yellow represented moderate acceptance, and red represented no acceptance. Two separate diagrams were created to capture customer acceptance and employee acceptance.

A third diagram was created to depict the current technical feasibility of allocating different tasks to the restaurant robot. The diagram was color-coded based on feasibility, where green represented feasible, yellow represented somewhat feasible, and red represented not feasible.

The three different diagrams were combined into a single comprehensive representation by layering them on top of each other. This unified diagram helped identify tasks that were deemed acceptable and feasible across all overlapping diagrams. It was found that the robot was most suitable for the tasks of carrying items between different positions in the restaurant but not for managing any actual service encounters such as ordering food, socializing etc. (mainly due to customers having difficulty accepting that a robot could create any value or meaning to these types of interactions, as well as employees' reluctance to hand over the task to the robot, as they found this to be the most valuable aspect of their job). This activity and analysis created a good understanding of what tasks that should be focused on in the upcoming design sprints.

Figure 10 – Overview of the final color-coded HTA diagram. The readable HTA can be found in Appendix C – HTA.

5.1.2 Market Overview

A market overview was done to gather information about existing restaurant robots. These robots could then be compared to our findings as well as form an understanding of how different solutions could be embodied. With the knowledge gained from the findings, it was also possible to identify different aspects of the existing robot solutions that were not considered favourable for acceptance within a Swedish restaurant setting.

5.1.3 Ideation

The ideation phase was, as described in the introduction (see *1.7 Process Overview*) divided into two different phases: high abstraction level ideation, and low abstraction level ideation. Firstly, the high abstraction level ideation was performed to generate broader and more general possible solutions, rather than focusing on specific details. The high abstraction level ideation aimed to create a product backlog (in this case, a list of possible features and functions to be further elaborated upon) which could be used in the low abstraction level ideation. In the low abstraction level ideation phase, the focus shifted to refining and handling specific details of the ideas in the product backlog. This was carried out through a series of design sprints, each concentrating on a specific aspect of the robot. Continuing, this subsection provides a detailed description of these design sprints.

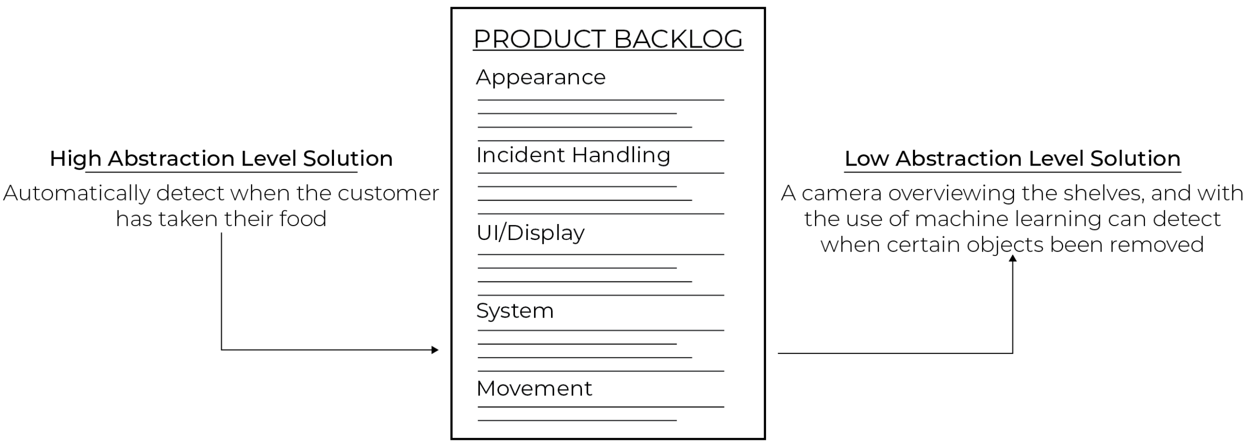

Figure 11 - Example of a high abstraction level solution, and its low abstraction level counterpart.

High Abstraction Level Ideation – Product Backlog

In the first stage of the ideation phase, high abstraction level solutions were generated focusing on the general considerations for creating a robot design facilitating acceptance. This involved taking the design guidelines and through brainstorming, ideating solutions that had the potential to create acceptance from the users. These high abstraction level solutions were then gone through one by one, and through placing them in scenarios, discussed if they had any potential. The solutions that were deemed to be interesting for further exploration were then placed in a backlog for further refinement in the low abstraction level ideation.

These high abstraction level solutions were then divided into six categories, based on similarities and how they were thought to aid the design process. The six different categories (that from here on will be referred to as design sprint) were shelves, incident handling, system, UI & display, movement, and appearance. These sprints were aimed to facilitate the generation of low abstraction level solutions, focusing on more detailed aspects of the categories. Subsequently, these sub-solutions could then be combined to form several complete robot design concepts. The order in which the design sprints were to be performed, was decided based on which areas of the robot design that was considered dependent on each other.

Low Abstraction Level Ideation – Design Sprints

Throughout the design sprints different alterations of brainstorming were frequently used as an effective way of generating a large number of ideas regarding how to interpret the guidelines. This often resulted in good material for discussion and further refinements through different media of visualizations and prototyping.

The design sprints also offered a structured approach to systematically focus on a manageable set of design guidelines at each stage facilitating iterative refinements throughout the process. The primary objective was not to create a fully operational concept encompassing all internal components. Instead, the focus was on developing an embodiment of the outlined guidelines. This embodiment served as a working example of how the various guidelines could be interpreted and implemented.

With every sprint, the guidelines were used as a base and could be questioned if they provided support in the design process, and/or if they needed clarification. From the knowledge gained through the initial stages of this project combined with insights gained from the actual design sprints, we were able to further ensure that they had the right emphasis to correlate to what was needed to create acceptance.

After the final concept had been established a secondary review of the guidelines was conducted since there were several guidelines that were used in multiple sprints. Therefore, some guidelines were further broken down based on how they had helped facilitate the design process in these different sprints.

Design Sprints

In this section, are each of the six determined design sprints presented. A brief description of how each sprint was conducted and their outcomes are given.

Sprint 1 - Shelf

The shelf configurations were seen as an important starting sprint since they determined the base structure of the entire robot. It started with a braindrawing session, with different spatial arrangements, as well as types of shelves being explored. Continuing, structural considerations of how the shelves were to be held in place were made.

After the initial brainstorming different shelf sizes and shelf configuration was explored through quick mock-ups of different shelf spacing and heights to account for reachability and accessibility. Moreover, shelf sizes were also explored to define measurements required for different loading capacities of common plate sizes.

This sprint resulted in three further refined shelf configurations and base structures of the robot focusing on different aspects of the design guidelines regarding the shelves.

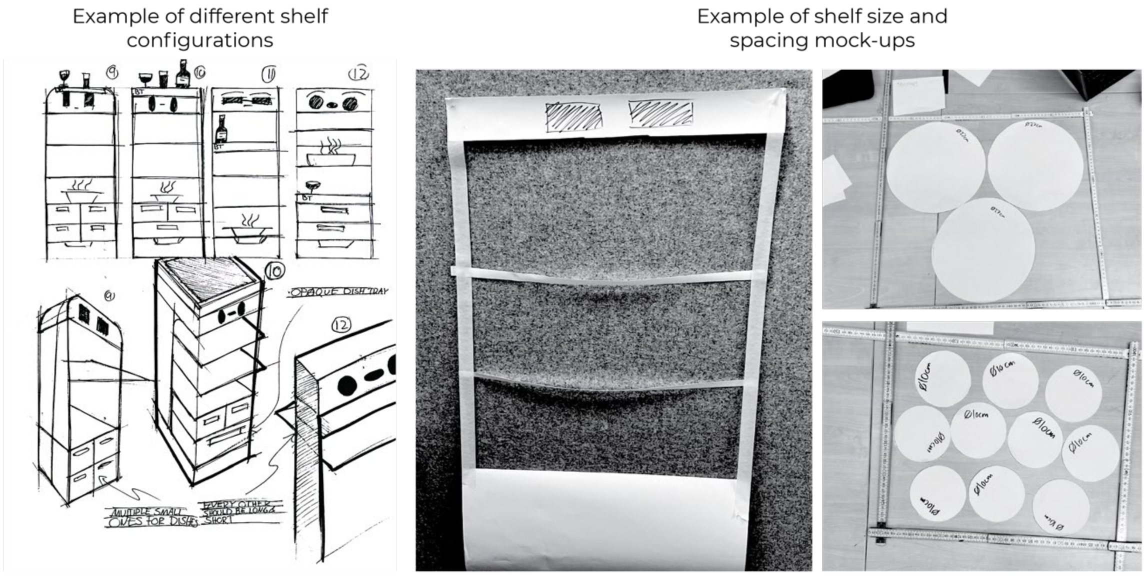

Figure 12 - Sketches and mock-ups from the shelf sprint.

Sprint 2 - Incident handling

Incident handling sprint covered potential incidents, errors, or problems that could occur and how the robot would behave in those situations.

The sprint started by listing the scenarios of possible incidents, errors, or problems that were mentioned in the interviews and identified in the observations and were aimed to facilitate the brainstorming session. These scenarios included everything from glasses falling over, people stealing the food of the robot on its way to the table, or if the robot was unable to reach its destination. The brainstorming ended in both written down ideas, and a few visualizations of how the robot potentially could prevent the incidents, how it could detect and recover from them, as well as what feedback the employees and customers should receive after the incidents.

New scenarios of incidents were then created based on the specific solution ideas, and a secondary brainstorming session was performed where sketches combining different solutions to handle the scenarios were generated. These solutions were closely related to the shelf configuration and were further iterated based on the different base structures originating from the shelf sprint.

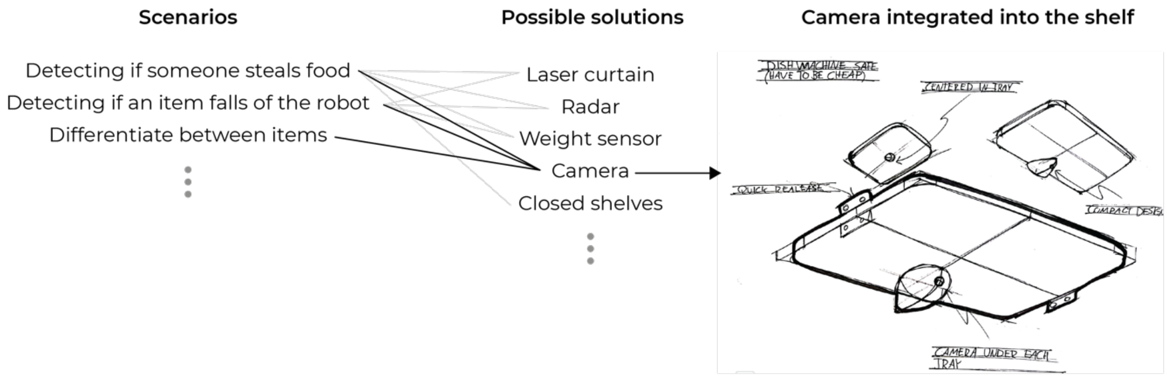

Figure 13 - Example of the incident handling process.

Sprint 3 - System design

The system design sprint was aimed to determine the necessary elements to create an efficient, easy-to-use, and useful system. In this context, we refer to the system being the overall structure composed of various interacting elements, which can be either tangible (like supporting devices) or intangible (such as rules, distribution of tasks, and information flow).

The sprint started by taking the tasks deemed acceptable in the previously made HTA, which were further elaborated upon, and possible interactions were broken down in more detail. Although the tasks regarding the service encounter were not deemed fully suitable to allocate to the robot in the initial HTA, it was regarded as relevant to explore for increasing its usefulness.

Firstly, a map(s) illustrating potential interactions with the robot was ideated and created to serve as a foundation for discussion. Following this, a brainstorming session was initiated to generate ideas on how the system could be structured to enhance these interactions. Moreover, it was deliberated to what extent the robot should incorporate current system solutions already integrated within restaurants. Results from this were for example different supporting devices that could help to further facilitate the interactions, the robot having different ways of operating and behaving depending on what type of task the robot currently is performing, how different tasks should be prioritized to create effective and efficient flow etc.

This design sprint did not generate any definitive sub-solutions but was rather an iterative process of creating a system enabling an efficient human-robot Interaction.

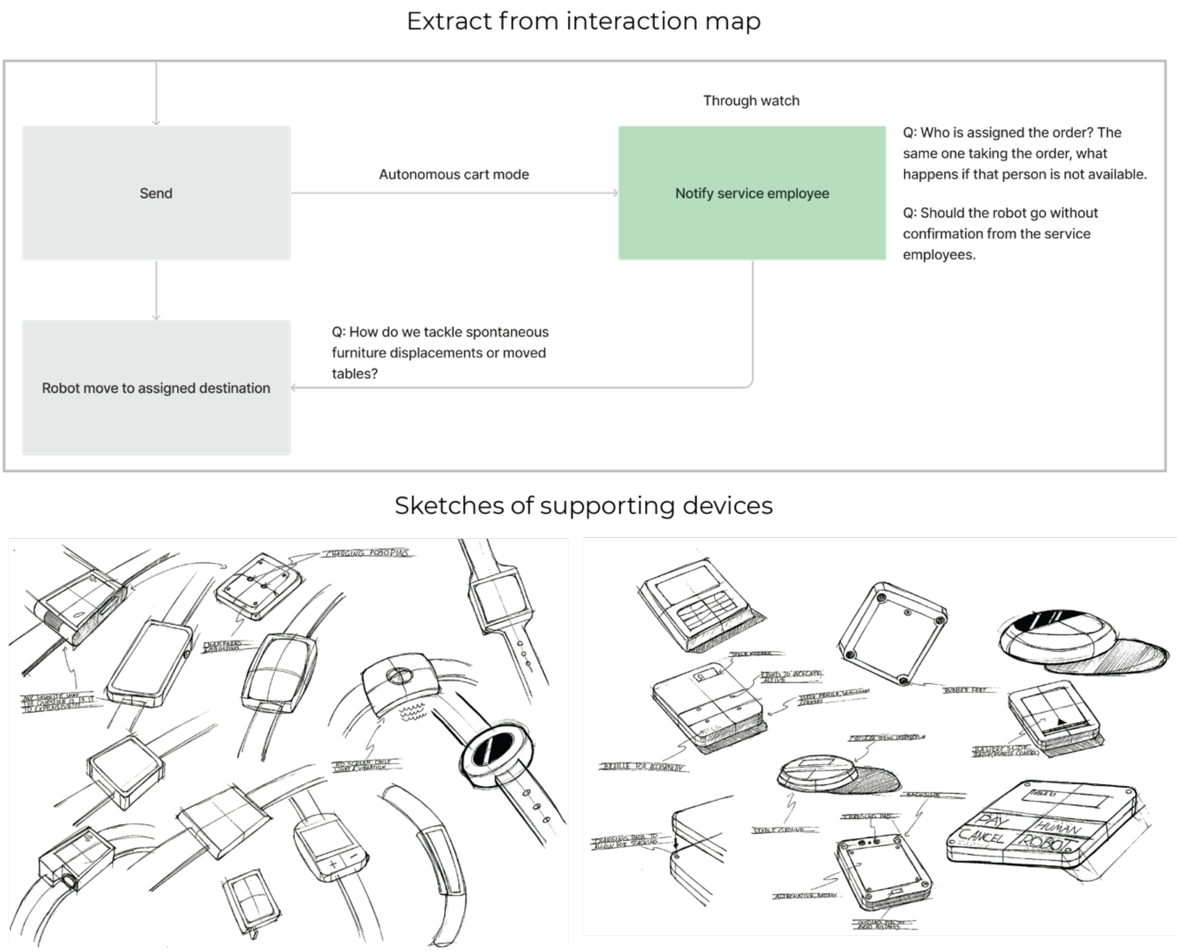

Figure 14 - Sketches and diagrams from the system design sprint.

Sprint 4 - UI and display

This design sprint focused on how the different points of interaction found in the system design should be facilitated and embodied in more detail through the user interface (mainly regarding the display).

The first brainstorming session focused on further elaborating on different scenarios that could occur during these interactions regarding the flow of information between employees, the interactive activities needed, and what feedback was necessary to facilitate efficient interaction etc.

From these scenarios, additional brainstorming sessions were conducted focusing on how this could be embodied in terms of screen placements, user interfaces (UI), ways for communication (speech, text, virtual eyes etc.), and how all of these could support each other. Examples of actual user interfaces were iterated upon to identify the different steps needed to facilitate a good interaction in terms of usability.

This resulted in multiple sub-solutions for screen placements, exemplifications of interfaces, speaker configurations, voice commands, etc., and furthermore, how these could be combined to facilitate intuitive and accessible interactions.

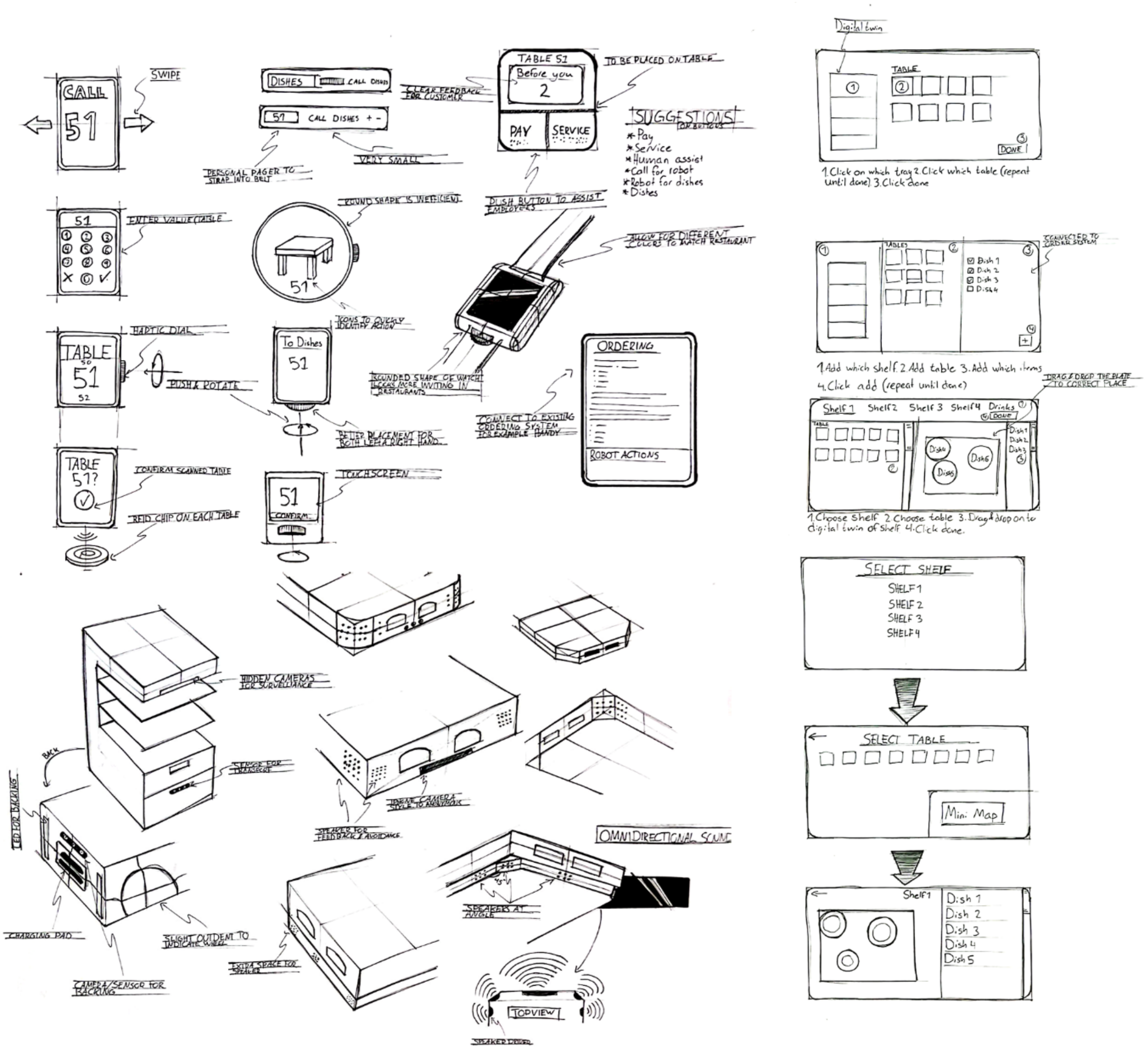

Figure 15 - Sketches from the UI and Display sprint.

Sprint 5 - Movement

The movement sprint was divided into two closely related phases, indication, and behaviour. Firstly, the indication phase consisted of a brainstorming session where sketches of different ideas on how the robot should indicate its presence and intention of movement were generated. This resulted in ideas such as virtual eye contact, indicators, floor projectors, sound output etc.

Moreover, these ideas were further iterated upon, and accessibility-related issues were discussed and tried to be resolved.

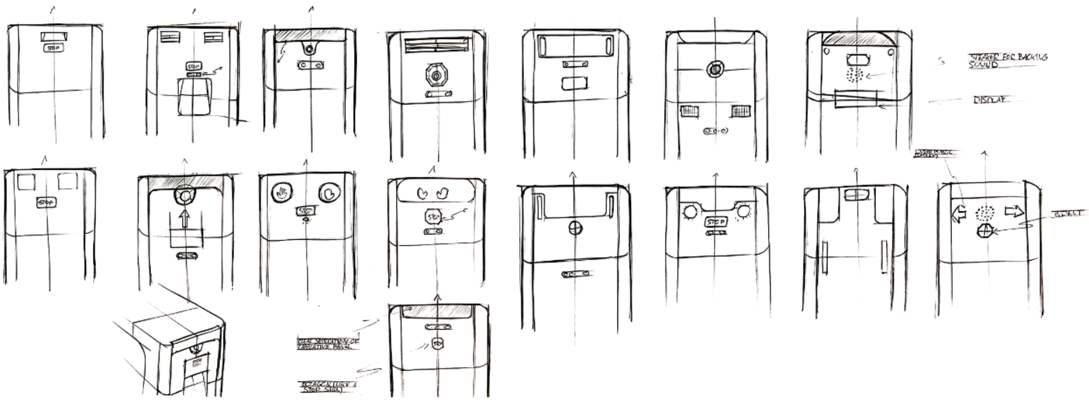

Figure 16 - Sketches of the backside, including indicators, speakers, etc.

For the behavioural part of the movement sprint, a 1:10 scale of a restaurant layout was created using paper cutouts. Multiple re-enactments of different scenarios were made to identify some critical situations that could be used as an exemplification of how the guidelines regarding movement could be translated. These scenarios were then further elaborated on to create examples of how the robot should behave and indicate its presence and intentions in those situations.

Figure 17 - Re-enactment of movement scenarios.

Additionally, virtual eyes were found to be an interesting way of indicating to passing humans that the robot has noticed them by mimicking eye contact. Therefore, several variations of virtual eyes were animated, and different types of re-enactments were performed to identify what features of the virtual eyes supported this indication.

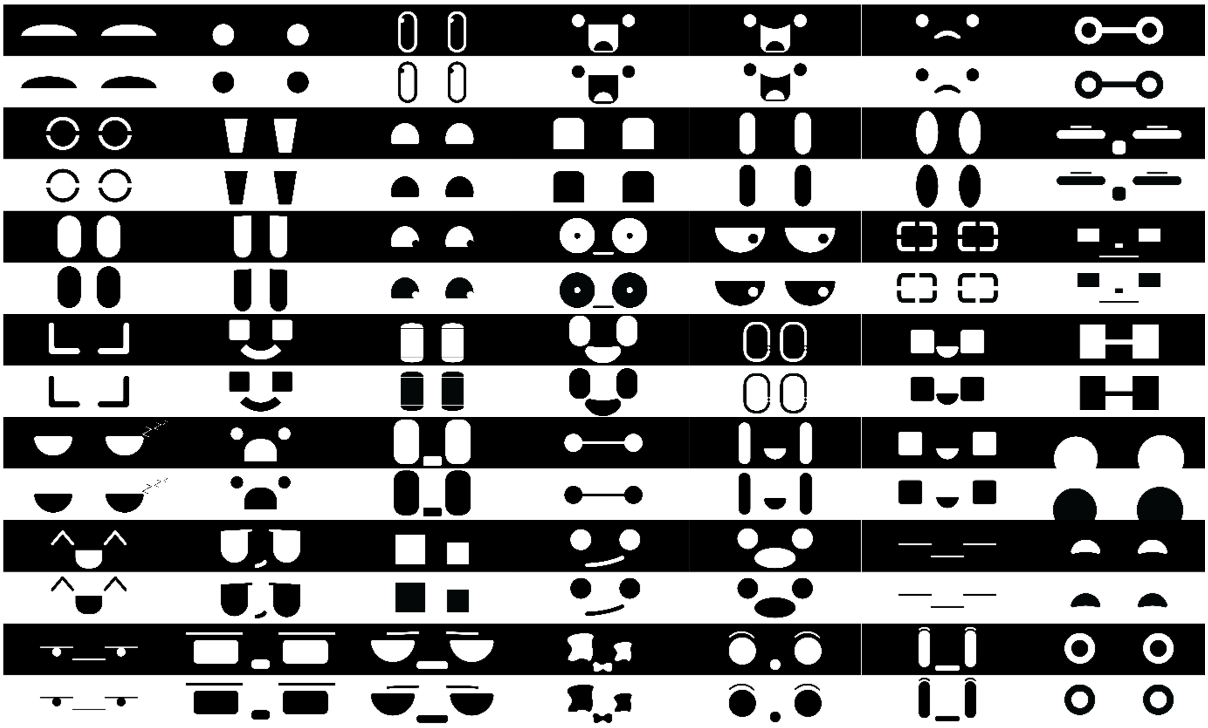

Figure 18 - Sketches of virtual eyes.

Sprint 6 - Appearance

This sprint started with the creation of an image board with examples of visual elements ranging from basic shapes to ensure that the colour, material, and finishes (CMF) all could be associated with the values of Scandinavian design. The brainstorming session in this sprint focused on the embodiment of the visual elements from previous sprints to create an appearance that matches the robot's functional capabilities, as well as lower the perceived risk to increase trust. This resulted in multiple sketches of for example indicators, speaker configurations, eyes, and how these could be integrated into the base structures generated in the shelf design sprint.

One other important aspect considered during the appearance sprint was ways of configuring different elements of the robot to match different restaurants' image. Different ideas regarding what aspects of the robot should be interchangeable and how this should be performed were generated.

To gain further ideas about how to incorporate the Scandinavian design a small workshop with experienced robot designers was conducted, where the base structure of the most prominent shelf configuration was used as a sketch underlay to facilitate ideas.

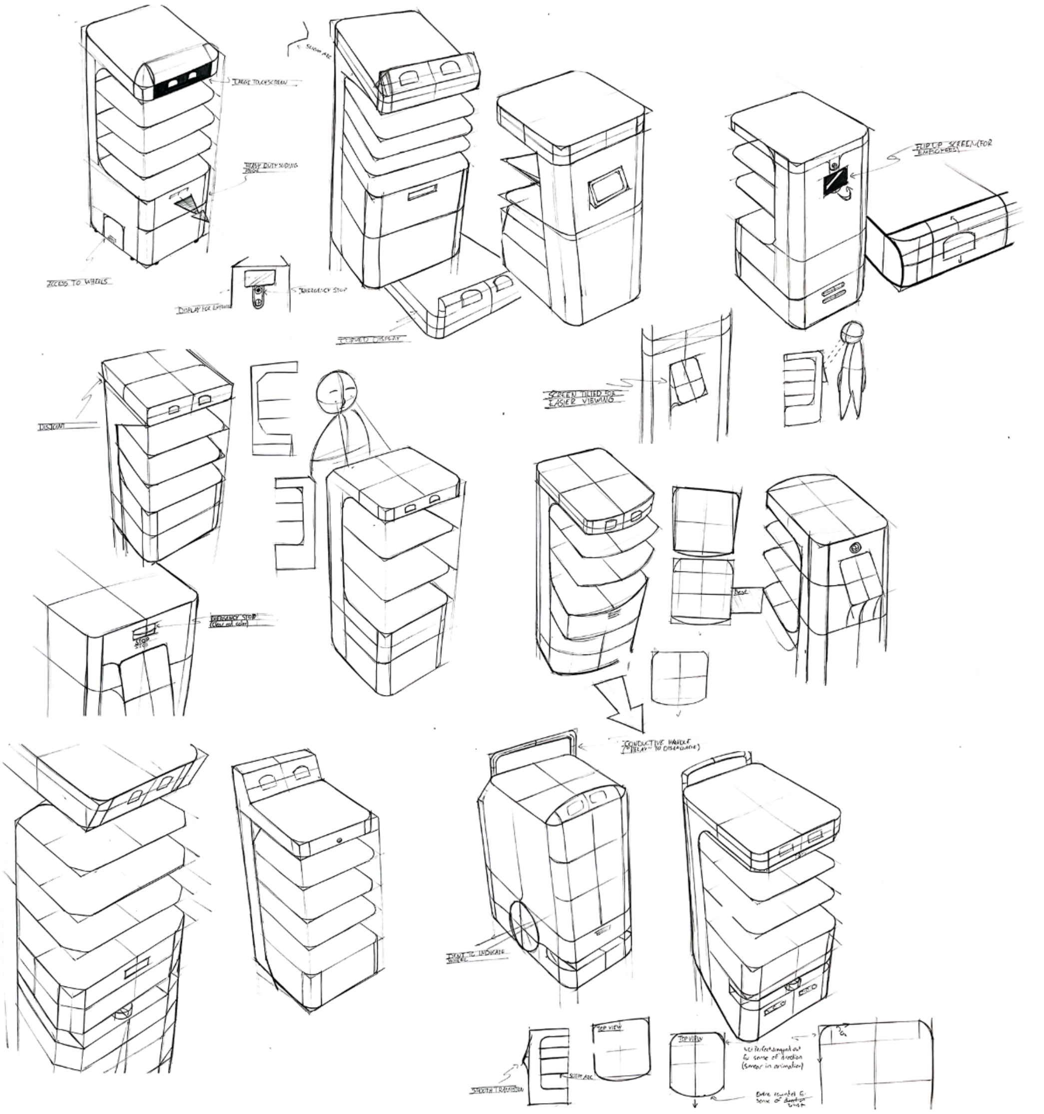

Figure 19 – Sketches from the appearance sprint.

Secondary appearance sprint

After choosing the final morphological concept, a secondary appearance sprint was conducted to finalize the concept. The first iteration of the concepts was computer-modelled (using CAD tools), and several outlined drawings were then printed as a base for further sketching and discussion. Ideas gathered from the first appearance sprint were then further elaborated upon in terms of panelling, radiuses, colours, materials, and other physical aspects that had not been fully decided upon yet. Thereafter, a secondary computer model was created where the final refinements to the physical appearance were made. This model was later rendered to create a more realistic visualization of the robot for presentation material.

5.1.4 Morphological matrix

After several sub-solutions had been generated throughout the six design sprints a morphological matrix was used to create and identify new ways of combining these solutions into more complete robot concepts. This was done by placing the sub-solutions from each design sprint in a spreadsheet. Each column represented the possible solution, and each row what it was meant to solve. These could then be combined to configure multiple different robot concepts.

The most prominent solutions from the matrix were then visualized through sketching, which could act as a base for discussion and further elimination of concepts by comparing them to the design guidelines. In the end, three distinct solutions were deemed possible to create acceptance from the users.

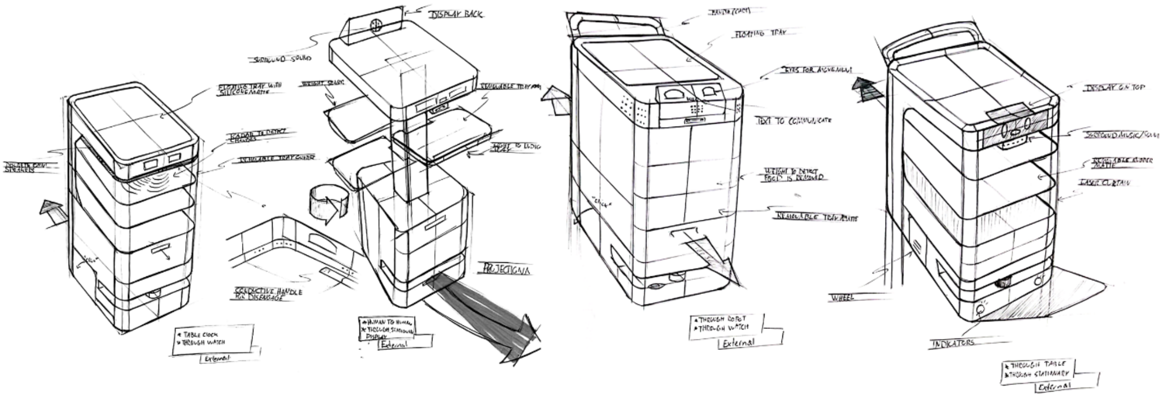

Figure 20 - Sketches of the robots resulting from the morphological matrix.

5.1.5 Weighted Evaluation Matrix

To select one solution to be further embodied, a theoretical evaluation in the form of a weighted evaluation matrix was used. This was done by selecting the most prominent guidelines, that could be converted into selection criteria. These criteria were then assigned weights from one to five reflecting their perceived importance for robot acceptance, where five were considered very important and one less important.

The three robot solutions resulting from the morphological matrix, and one existing robot on the market (the robot which had been a part of the observation), were then placed into a weighted evaluation matrix. One of the robots was regarded as the reference, which the performance of the remaining three robots was compared to. For each selection criterion, the robots either received a score of 1, 0, or -1.

- Score of 1: the robot fulfilled the criteria better than the reference robot.
- Score of 0: the robot and the reference robot fulfilled the criteria equally well.
- Score of -1: the reference robot fulfilled the criteria better.

The score of each selection criterion was then multiplied by their respective weight and summed to give the total score of the robot comparison. A negative total score on the evaluation matrix indicated a performance below the reference robot, while a positive score indicated a higher performance. This process was repeated a total of four times, for each robot to be able to act as the reference.

This method enabled a comprehensive comparison of the four robots based on the established criteria. It also facilitated the identification of one superior concept by providing a structured approach to ranking and evaluating the different robot designs. Furthermore, the matrix revealed areas for potential refinement within the superior concept.

5.2 Result

In this section, the design guidelines, and examples of how they could be applied are presented. This is done by describing a restaurant robot (the design concept) that was developed with the design guidelines as a foundation, as well as outlining what guidelines affected what in the design. A full overview of all the design guidelines can be found in *Appendix A – Design Guidelines*.

Figure 21 - An overview of the resulting robot concept.

5.2.1 Design Concept Description with Associated Design Guidelines

General Description

The final robot concept was based on the predefined robot platform mentioned in *1.6 Delimitations*. Figure 22 and Figure 23 showcase the entire robot and highlight some of the most important features that will be discussed in this chapter.

The shelves are spatially arranged and designed to be reachable, as well as, accessible from both a standing and sitting position. Furthermore, the robot is equipped with multiple cameras overviewing the shelves and the surroundings to enhance the interactions while also enabling real-time incident detection.

The robot has been limited to only serve one group of guests at a time to ensure adequate temperature of the food, as well as making human-robot interactions less complicated. Depending on whether it is to be used to manage the entire serving encounter or to be used as an autonomous cart transporting items in-between different areas of the restaurant to support employees, the robot has two different ways of behaving.

Two supporting devices (a watch and a table pager) are also available to further assist both employees and customers with different interactions. The robot display, which is complemented by multiple directional speakers, facilitates most communication between the users and the robot. Interactive outputs can be customized through a low code programming interface, allowing the restaurants to stylize different interactions to match their desired profile.

The physical appearance is based on the principle of form following function and prioritizes a clean aesthetic with light colours and soft shapes. Upon purchasing the robot, different colour and material options can be selected, as well as shelf configurations determined to further enhance the restaurant's ability to customize the robot to match their desired profile and intentions for implementation.

Figure 22 - Front of the robot.

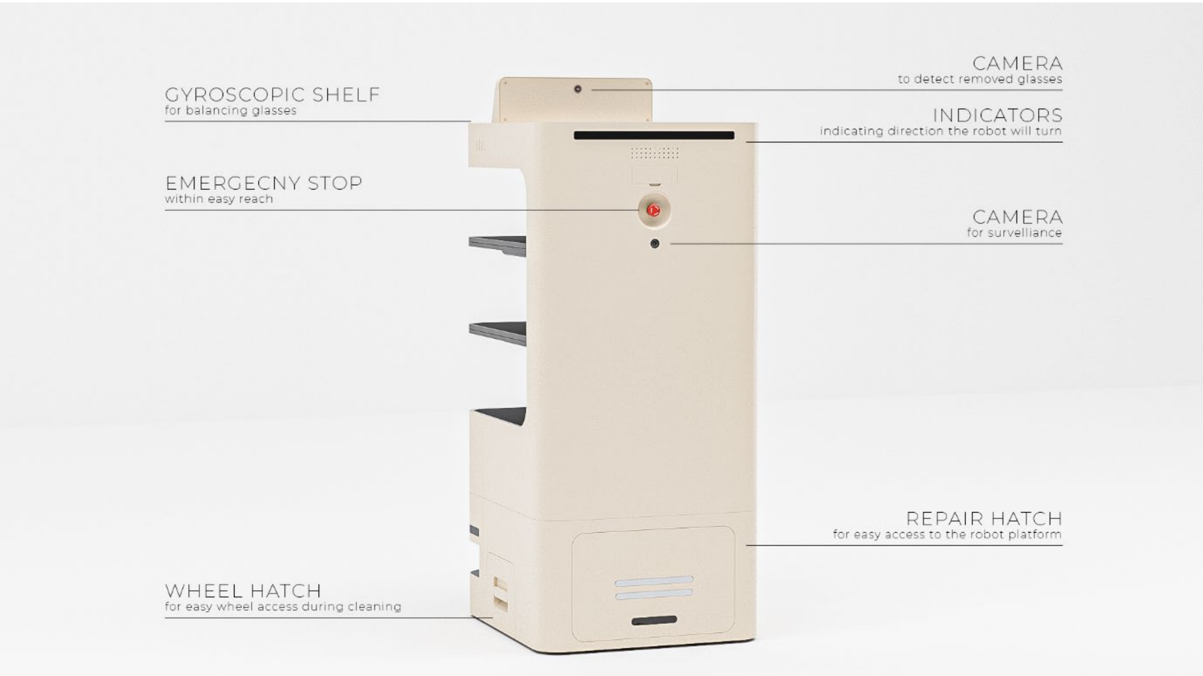

Figure 23 - Back of the robot.

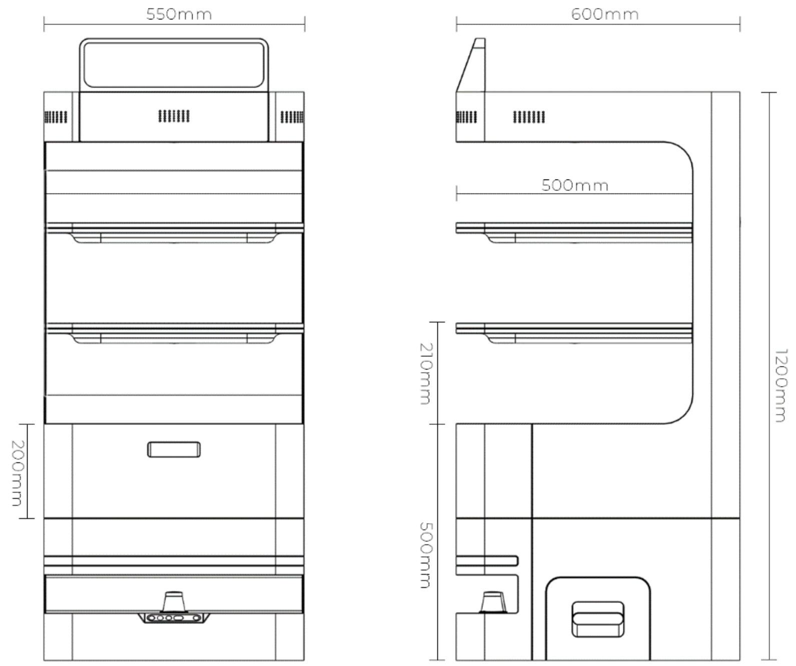

Figure 24 - Measurements of robots.

Shelves

To accommodate for easy access of the items placed on the shelves from both a standing and sitting position, the upper shelf is placed at 120 centimetres above the ground, and the lowest at 55 centimetres (with the remaining shelves evenly distributed therebetween). For the remaining space between the lowest shelf and the robot platform, there is an extendable storage compartment (in the form of a drawer) which could be used for storing additional cutleries or other necessities that may be required during a serving. To be able to access the shelves from as many angles as possible, the shelves are only attached to the rear of the robot. In order to ensure stability and that it can handle the weight of the items being carried, the shelves feature a built-in steel rod that also serves as attachment points to an inner supporting structure (see Figure 27).

Two different types of shelves could be found in the robot, one self-balancing shelf at the top and three stationary shelves below. The self-balancing upper shelf has two perpendicular motors, which are controlled by a gyroscopic sensor, to keep the surface level. This is to prevent liquids from spilling or glasses from tipping over while the robot is accelerating and tilting. The self-balancing shelf size is 32 x 38 centimetres to accommodate 10 average-sized drinking glasses, while the stationary shelf size is 50 x 55 centimetres to accommodate three large 27 centimetres diameter plates (meaning a total of 12 plates could be delivered at the same time).

For easy cleaning, all shelves are equipped with a detachable rubber cover that can easily be replaced and cleaned in the dishwasher when needed.

Figure 25 - Detachable silicon cover.

Figure 26 - Self-balancing tray carrying wine.

Figure 27 - Steel rod reinforcement, to handle the weight.

Table 2 - Guidelines impacting the design of the shelves.

Guidelines	Customer / Employee	Impact on design
Food and drinks should be in a reachable height for sitting and standing.	Customer	The lowest and highest trays are placed on a level (55cm and 120cm above ground) that is suitable for both a standing and sitting position. This was done by testing different heights of shelf placements.
The robot should be designed to assist in repetitive and time-consuming tasks.	Employee	The shelves are designed to carry as many plates and glasses as possible. This is to avoid employees having to constantly go to the kitchen and carry the plates themselves.
The robot should be able to transport food and drinks to customers without spilling.	Employee	A self-balancing shelf was designed and added to the robot to minimize the risk of spills to the greatest extent possible.
Features and functions of the robot should be customizable in a way that enables optimized use in different restaurant settings.	Employee	The option exists to order different shelves as well as spatial configurations depending on the use intentions.
The robot design should focus more on functionality than anthropomorphic features.	Employee and Customer	Larger shelves were prioritized over a human-like appearance, as the latter would only be able to carry one (or max two trays at a time).
The robot should be designed in a way that enables it to be easily cleaned.	Employee and Customer	Removable silicon covers were integrated into the shelves, which could be easily removed for easy cleaning. The covers feature a pattern that allows the water to run off when washed. Additionally, the self-balancing tray includes a detachable catching tray that can be easily cleaned.
The shelf design should be optimized to accommodate the anticipated quantity of plates as well as standard plate sizes commonly used in the restaurant segment.	Employee and customer	Each shelf, meant for transporting food, was dimensioned to fit three plates with a diameter of 27 cm (which can be considered a standard plate in restaurants).
The robot should be constructed to handle heavy loads that match the number of desired plates.	Employee and Customer	Each shelf, meant for transporting food, has been fitted with internal steel rods, to handle the weight of three plates with food.
The robot should be able to operate within Swedish wheelchair accessibility dimensions.	Employee and Customer	The dimensions of the shelves (consequently affecting the robot) were considered to keep it within the norm of measurements for accessibility.

Incident handling

To monitor the food being delivered to the customer, above each stationary shelf there are embedded cameras that provide an overview. These enable the use of object detection and other machine-learning algorithms, to be used in multiple instances. For example, when the robot is leaving the pickup position, these cameras can detect whether someone or something interferes with the food on the way to the table, or if something has fallen over. Once the robot has arrived at the table, these cameras can also detect when all items have been removed from the robot, and automatically leave without any input from the user (avoiding confusion and awkward interactions). This also allows customers to be notified if items were to be forgotten on any of the shelfs. The self-balancing top shelf could not be equipped with a camera overviewing the shelf and therefore does not have the same safety features as the stationary shelves. However, the camera on the back of the display console can detect if all items have been removed from the shelf. Additionally, there is a camera embedded into the display, as well as one camera located in the back that is used for documenting incidents during the robot's travel. In the case of an incident, the robot stops, and the last ten seconds of the camera footage before the incident is saved. The screen then displays an error message stating for example, "A glass has fallen over, employees are on their way", and the employees get notified through the watch what type of incident has occurred and where to efficiently assist and recover the situation. If necessary, the employee can review the footage to further establish the cause. The camera footage can only be accessed for review after a notified incident and cannot be permanently saved. Furthermore, all faces captured are automatically blurred by built-in software. This is to ensure that the focus is put on the incident itself, and not the individual who may have caused it, with the aim of enhancing the transparency of the robot and its actions. The cameras embedded in the screen and in the back also enable the robot to detect the type of objects that hinder its path, allowing it to notify employees.

Furthermore, on the back of the robot is an easily accessible emergency stop button located. The emergency stop button is a standardized component that is easily detected, and its purpose is understood by any individual (allowing it to be quickly identified and engaged in an emergency).

Figure 28 - Embedded cameras.

Figure 29 - Example of how it could look in case of a wine glass that has dropped.

Table 3 - Guidelines impacting the incident handling.

Guidelines	Customer / Employee	Impact on design
The robot should inform the employees in case of incidents or malfunctions in order to resolve them quickly.	Customer	In case of an incident (the robot drops a plate etc.), the employees get notified through a smart watch that something has occurred, which requires human assistance.
The robot should have a clear way of displaying the reason for failure.	Employee	When an incident occurs, employees can choose to replay the footage. In this replay, all faces are blurred to maintain anonymity and ensure the focus remains on the scenario rather than assigning blame to any individual.
An emergency stop button should be easily identifiable and reachable.	Employee and Customer	A standardized emergency stop button has been placed at an accessible height on the back of the robot, which is easy to reach in case of an accident.
If the robot collects data, it should be transparent about what data it collects and how it may be used.	Employee and Customer	If the robot is involved in an incident, the screen displays a text describing that the footage of the incident has been saved and that the employees are on their way to assist and review the incident.
The robot should only present collected data when relevant and necessary.	Employee and Customer	The data can only be able to be accessed after a recorded incident and cannot be permanently saved.

System

To avoid suboptimization when implementing a restaurant robot, rules regarding the flow of tasks were determined, as well as two supporting devices were designed:

Watch

The watch acts as a supporting device that enables the employees to receive feedback on the robots' current position and initiate tasks more easily. Through the app, the employees can access information and receive notifications regarding the robot's current progress or requests placed by the customer (which is described below). It also allows employees to request certain tasks from the robot. It is an app-based interface allowing it to be accessible for all types of smart watches.

Table pager

The table pager is a supporting device that is located on each table, to allow customers to have better control over their service. Through the pager, the customers can call for human service in case of for example delivery problems or questions regarding dietary restrictions. The table pager is equipped with an energy-efficient E-ink display allowing the customers to receive feedback upon interaction. When the server button is pressed the employees, get notified which table is looking for human assistance, and the display then shows a text stating that servers are informed and on their way to the table. Additionally, a call for payment is also located on the pager which is a feature that automatically prepares the bill for the visit. The table pager also features a cancellation button, allowing the customers to recall a service or bill request.

Figure 30 - Table pager.

Figure 31 - Watch.

Flow of tasks – Automated Task Management System

The automated task management system is built on a flow of tasks that employees can request the robot to initiate through supporting devices. Requested tasks can then be accessed through the watch and other stationary devices allowing employees to receive an overview of the robot's progress. The tasks can be divided into three main categories, serving food, serving beverages, and collecting dishes. Within the restaurant, the robot is meant to be assigned one base position, one food pick-up position, one beverage pick-up position, and a dish unloading position (as well as a "home" position, where it charges). At each pick-up position, a button should be placed that can call the robot to the set location. The base position should be strategically located to have good accessibility to both food and beverage pick-up positions. At the base position, the robot awaits a task request for one of three listed tasks. Depending on the intended type of service the restaurant aims to achieve, the two serving tasks could differ. Therefore, the two following service modes were created:

- Autonomous serving mode is when the robot is loaded in the kitchen and sent to manage the entire service encounter at one specific table. After arriving at the table, the customer unloads the food or beverages, and the robot returns to the assigned base position awaiting the next task. In case of inconvenience, the customer can call for human assistance through the table pager.
- In autonomous cart mode the robot is used to autonomously transport items from a pick-up position to a table. When a food or beverage pick-up task is initiated, the server responsible for the order is notified that the robot soon will move to the table connected to the order. The server and robot then meet at the table and the server unloads the items before the robot returns to the assigned base position. This allows for the server to be more present in the dining area on the guests, while also minimizing repetitive heavy lifting.

To ensure adequate delivery temperatures and to minimize logistical complications the robot is limited to only handle one delivery order at a time. Since food and beverage deliveries are time-sensitive activities, they are more prioritised than dish collection. Beverages are expected to be delivered within a short timeframe upon order, and food is necessary to be delivered shortly after completion as a way of ensuring adequate temperature. For perceived hygienic purposes, the robot should not visibly carry both collected dishes and food or beverages simultaneously. If one robot is used for both transporting food or beverages and dishes, a request for dish ‘collection should only be initiated right after a serving task. The following scenario will further explain the systematic considerations.

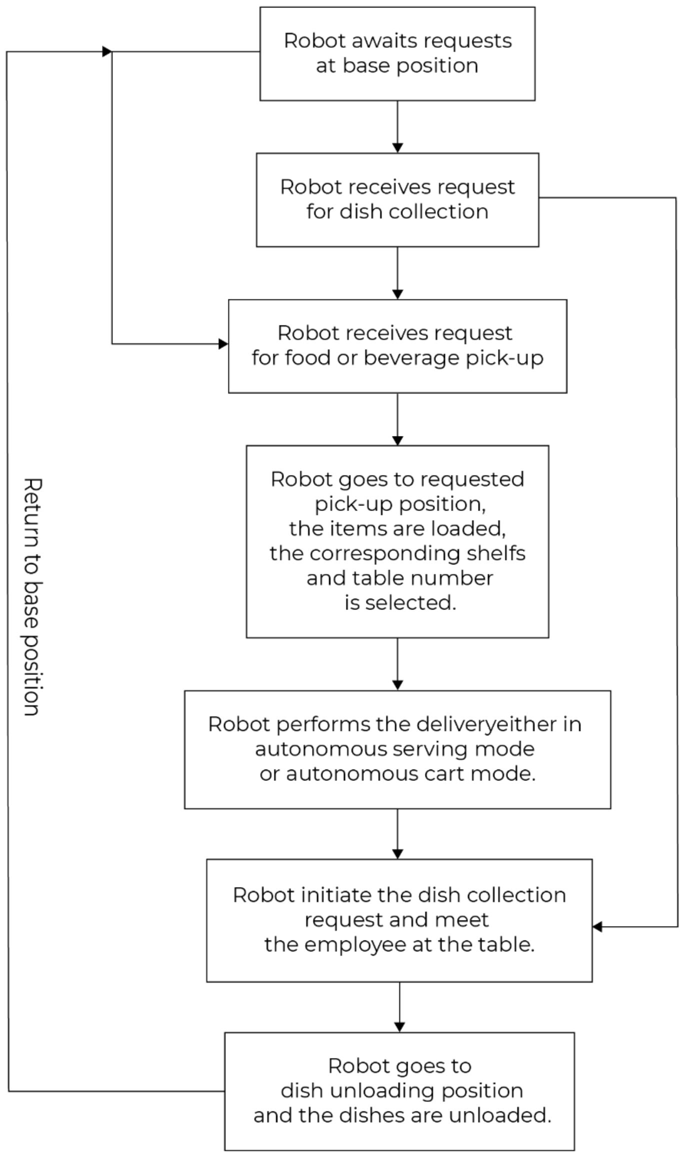

Figure 32 - Exemplification of robot tasks flow.

Scenario

This scenario captures the most intricate situation where one robot is used as an autonomous cart for all parallel tasks.

- Klara is working in the kitchen and her responsibilities include loading food and unloading dishes from the robot.
- Tom works as a server and his responsibilities include taking orders, preparing beverages, serving food and beverages from the robot to the guests, and loading dishes onto the robot from the tables.
- Lisa and Jonny have the same job as Tom.

Tom requests the robot to go to table 21 for dish collection through his watch (see Figure 33). The robot stays in the base position awaiting food or beverage delivery to be executed before the dish collection request is initiated. Two minutes later Klara from the kitchen requests a food pick up to be transported to table 9. Lisa who took the order from the of guests at table 9 gets a notification on her watch that the order pick up is requested so she can get ready to soon meet the robot at table 9 and serve the company. At this stage, Tom can see that his dish collection request is preliminary set to be initiated after the serving at table 9. Before the robot is loaded with food to table 9 Jonny requests a beverage pickup at the bar for table 12. Since food and beverages are prioritized, his pickup request is placed as the next activity and Toms's dish collection request is now placed as the third activity. After Lisa has meet up with robot and served the guests at table 9 the robot moves to the beverage pick up destination where Jonny is ready to load the beverages and follow the robot to table 12. As the robot approaches table 12 Tom gets a notification that his dish collection is soon to be initiated at that stage that activity will not be overruled by any food or beverage request.

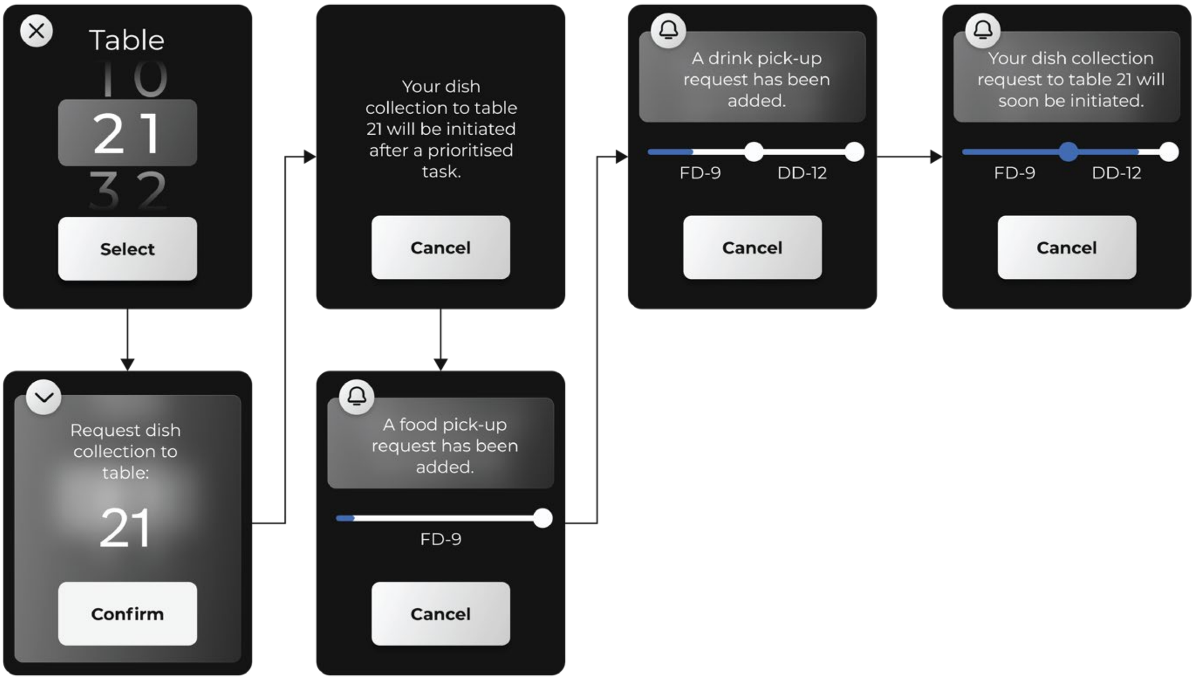

Figure 33 – Example of the watch interface shown for Tom.

Table 4 - Guidelines impacting the design of the system.

Guidelines	Customer / Employee	Impact on design
The robot should be designed to assist in repetitive, heavy and time-consuming tasks.	Employee	The robot has been designed to operate automatically, eliminating the need for employees to constantly go to the kitchen.
The system should be optimized in full, to avoid suboptimization.	Employee	Additional tools have been added to the system (the watch and table pager), to complement the robot.
The robot should provide relevant statics of how it is used.	Employee	At any given point, the robot can display statistics of how many tables it has served, when it is used the most, how many meters it has travelled etcetera.
The robot should only be able to deliver food to one company (table) at a time.	Employee	There is no option to set routes (sequence of tables it should go to) for the robot.
The restaurant should be able to operate, without the robot.	Employee	The robot is designed to integrate seamlessly with existing restaurant systems, by for example not being dependent on being aware of orders etcetera.
Tasks or sequences of tasks should have to be initiated by an employee.	Employee	An employee needs to actively input what the next action of the robot will be.
The robot should be able to complete its initiated tasks autonomously with minimal human supervision.	Employee	The operations (which is seen as a part of an action), that could be automated, have been automated to the greatest extent possible.
The robot should be flexible in what type of tasks it can perform.	Employee	The robot features different modes for various tasks, which can be changed depending on what the restaurant prefers.
The robot should provide additional benefits to existing solutions.	Employee and Customer	The robot allows for the autonomous transportation of food and dishes, which cannot be achieved by a manual serving cart.
The expected level of service should not be negatively affected by the use of a robot.	Employee and Customer	The robot's autonomous cart mode enables employees to engage more with customers and remain present, by reducing the need for constant trips to the kitchen to bring food
The robot should fulfil its tasks to a satisfactory level which improves the work quality.	Employee and Customer	The usefulness has always been in focus, for the robot to actually assist the employees, so it is not only used as a marketing tool that gives a "WOW" experience once.
The robot should facilitate better service opportunities for the employees.	Employee and Customer	The autonomous transportation of food and dishes enables employees to be more present in serving situations.
The robot should be pairable with additional technological systems.	Employee and Customer	The robot has an open API to allow other parties to create technologies that could be paired with the system.

UI and Display

The robot is equipped with one multipurpose touch screen (hosting all user interfaces), which is angled at 20 degrees, and centred at 125 centimetres above the ground. This placement enables it to be reached for both customer and employee interactions, and due to its angle allows information on the screen to be seen from both a standing and sitting position. The top shelf is also equipped with ultrasonic speakers enabling directed speech and sound output. These speakers can transmit very directed sound waves and allow the output volume to vary in different directions, to minimize unnecessary noise pollution. The robot uses both speech and text to communicate with the user, for better accessibility. During a customer interaction, the robot uses predetermined phrases with clear and directed messages that leave minimal room for potential questions (as the robot is not able to process speech and answer those questions). For this reason, the robot design does not feature anything that is to be interpreted as a mouth, to further emphasize that it is not to be spoken to.

To enhance customizability, these different interaction outputs are interchangeable, using a low-code programming platform. With this, the restaurants can easily change aspects such as preprogrammed phrases, voice, sound etc. This also creates the opportunity for further developments and updates to be installed after the purchase.

Through the robot, it is also possible to access different statistics regarding how the robot has been used. For example, it could be the number of times it has picked up food, the total distance it has travelled, the number of incidents etc. This allows employees to receive better insights into how the robot is used which could help to identify further optimisation opportunities.

Depending on what task the robot is set to perform, it adjusts its interface accordingly to create a more efficient and effective interaction. Below are two examples of employee and customer interactions with the robot in autonomous serving mode.

Employee

The robot interface does not rely on any order information but rather relies on the input of employees. This is to allow the restaurant flexibility when choosing an order information system. The interface is designed to reduce the number of steps the employees must perform to reach the desired outcome, as a too long interaction would cause frustration. This is exemplified through a pickup position interface with a three-step interaction showcased in Figure 34.

- The employee selects the table number connected to the order from the preloaded interface.
- The employee selects the shelves that are loaded with the order.
- The employee confirms and sends the robot to the table.

Figure 34 - User interface at pick-up position.

In case of an order with dietary preferences included, additional steps are needed to ensure sufficient customer feedback. After pressing the dietary preferences button, the program can detect all shelf perimeters and a virtual top view representation of the shelf containing the item is created. By clicking on the corresponding virtual plate containing the item with dietary preferences it gets highlighted and can thereon be tagged with one of the most common dietary preferences in case someone orders the same meals but with different dietary preferences. This way, additional feedback is created to better facilitate the interaction in more critical situations.

Customer

To make the robot more accessible for everyone, it is designed to receive minimal physical input. Therefore, during customer interactions, it is mainly using speech and text for feedback. Upon delivery, when the robot is in autonomous serving mode, the robot will announce the table number and the shelf placement of the items through both speech and text on the screen. In the case of an order with dietary preferences, the customer will receive a virtual top-view representation of the shelf with the item highlighted (see Figure 35). When the item with dietary preferences is removed the customer will receive additional speech and text feedback. Using the cameras the robot can detect when all items are removed from the shelves. The robot then automatically refers to the table pager in case of questions or other requests before driving off.

Figure 35 - Example of the selection of dietary preferences.

Table 5 - Guidelines impacting the design of the UI and display.

Guidelines	Customer / Employee	Impact on design
The anthropomorphic features should not be exaggerated.	Customer	The robot features eyes that are not perceived as human-like, and instead are a representation of it.
The robot interaction should have an appropriate level of perceived professionalism.	Customer	The robot is configured through a low code programming platform, in which the restaurant is able to customize the level of playfulness that the robot expresses to match the restaurant's desired profile.
The robot implementation should enable finished food to be delivered within a similar time frame as an all-human system.	Employee	The UI of the robot is designed with minimal steps and input, for example when loading dishes. In addition, the robot can only serve one company at a time to avoid time-consuming bottlenecks.
The appearance and perceived functional capabilities should match.	Customer	A mouth has deliberately not been added to the robot to prevent any perception that it is capable of engaging in conversations.
Robot service interactions should be performed within a similar timeframe as of human service interactions.	Customer	Minimized interactions that could lead to confusion. For example, the robot recognizes when all plates have been taken, with the use of the overviewing camera, and then drives away without requiring any physical input.
The robot should have features that could be changed between different restaurants to create a unique experience.	Customer	With the help of the low code programming platform, restaurants can change for example eyes, voice, personality, phrases, behaviour etcetera, to match their desired profile.
The robot should provide instructions during an interaction.	Employee and Customer	Visual and auditory cues have been added to facilitate interactions, by indicating the next cause of action etcetera.
The robot should give the user a clear indication that it or the user has completed a task successfully.	Employee and Customer	The robot confirms by speech that the customer has successfully taken the food.
The robot UI should be designed based on an established usability framework.	Employee and Customer	The "6 Principles Of Design", by Donald Norman, is a well-established, usability framework that has been utilized when designing different user interfaces.
The robot should make use of technologies that are perceived as reliable and mature.	Employee and Customer	An active decision has been taken to avoid speech recognition as the technology is not deemed ready. Instead, it relies on conventional screen based communication.
The robot should have a non-disturbing level of communication.	Employee and Customer	The robot features directional speakers which enable the robot to address only the table it is serving, thus avoiding disturbing other tables.

Movement

When the robot is moving between different positions, the screen showcases a pair of virtual eyes. With the help of the screen-embedded camera, the robot can detect faces and mimic eye contact with people moving in the opposite direction. This is to create a more intuitive way of confirming that the robot is aware of the person's presence. In this case, the eyes consist of two circles acting as pupils, that move and skew to resemble eye movement (see Figure 37). For an indication of movement, the robot also uses sound output such as gently humming a song (to create awareness of its presence, giving it a higher level of accessibility). With the ultrasonic speakers, this audio output can be adjusted in different directions to cause less noise pollution. This allows the robot to output sufficient volume only in its driving direction, while not disturbing eating customers too much. These interactive features (eyes and sound) can be customized using the low-code programming environment. To indicate directional changes the robot also uses the indicators, both the front and the back. In addition to the indicators the eye located in the turning direction also serves as an indicator, by blinking in a vibrant, orange colour. The camera in the back also allows the robot to drive backwards while still being aware of its surroundings. This is paired with a separate sound, indicating backward motion and is used to avoid getting stuck or blocking the way for someone, without the need for a complete 180-degree turn.

Figure 36 - Directional speakers, with variable volume.

In addition to its interactive features, the table pager has a built-in Bluetooth transceiver assigned to the specific table number that allows the robot to find its service position after some table displacement. For this reason, the table pager should be positioned at the table end closest to the appropriate serving position for the robot.

Figure 37 - Eyes looking in different directions.

The robot also adjusts its movement behaviour according to what type of task has been initiated. For example, when carrying food or beverages the robot drives more aggressively to ensure the right temperature and expected service time. Here are two scenarios, that describe some movement behaviour of the robot when serving food or beverages (Driving more aggressively).

Lastly, underneath the top shelf is a conductive handle that disengages the wheel brakes allowing the employee to quickly adjust the robot's position manually.

Scenarios

When entering the corner, the robot slows down and slowly positions itself for the upcoming turn while activating the indicators. Depending on the action of the crossing person and their distance to the corner, the robot adapts to the situation. If the person is at a far enough distance the robot will enter the pathway while signalling both with the indicators and sound. If the person is close to the corner but appears to stop to let the robot pass the robot proceeds to take the turn and thanks the person for stopping. If the person keeps moving forward the robot notifies the person that it intends to wait for their passing through speech and text while slowly moving forward to keep momentum and further indicate that it is in a hurry.

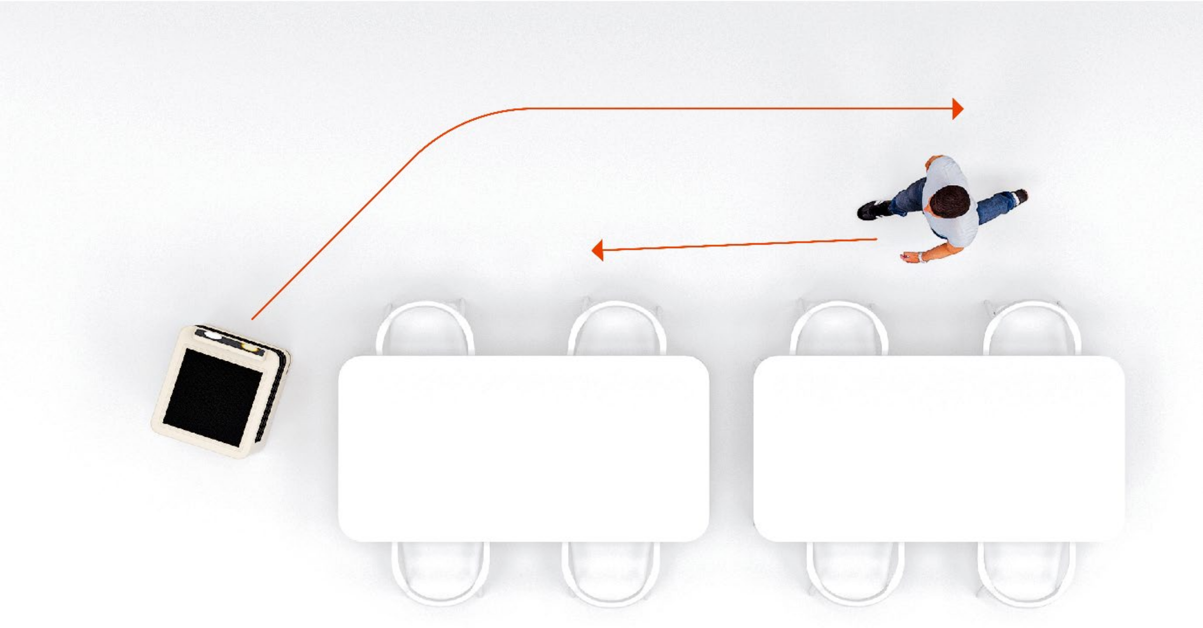

Figure 38 - Example of robot behaviour when exiting a corner, in a situation with a relatively far distance between human and robot.

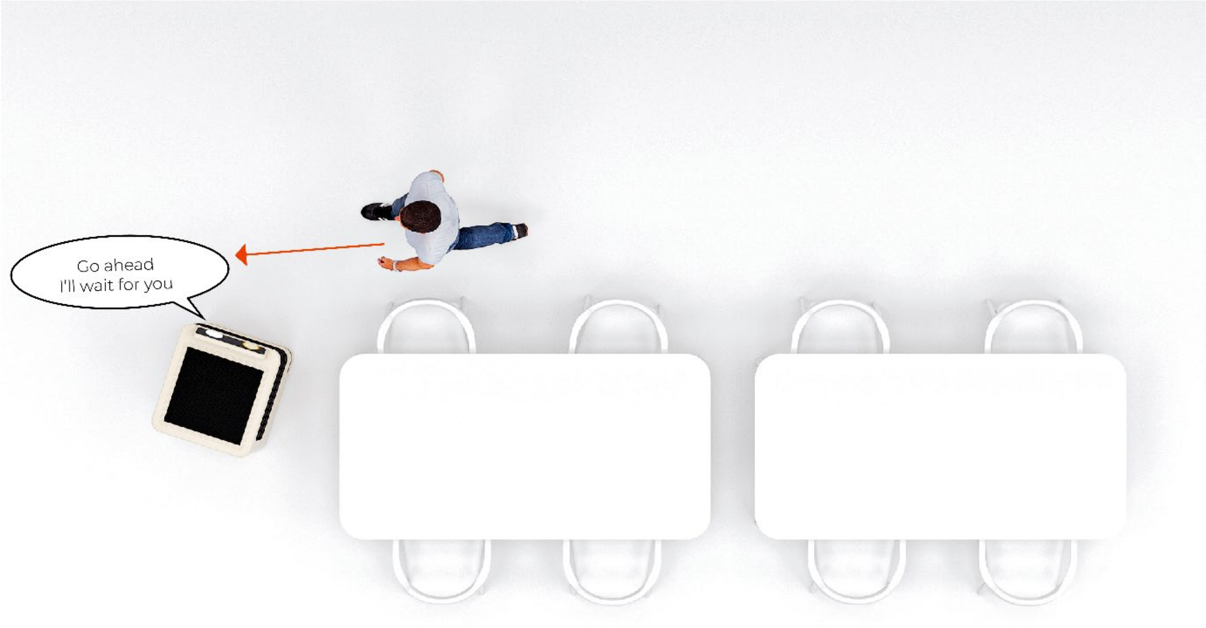

Figure 39 - Example of robot behaviour when exiting a corner, with a close distance between human and robot situation where the human does not stop.

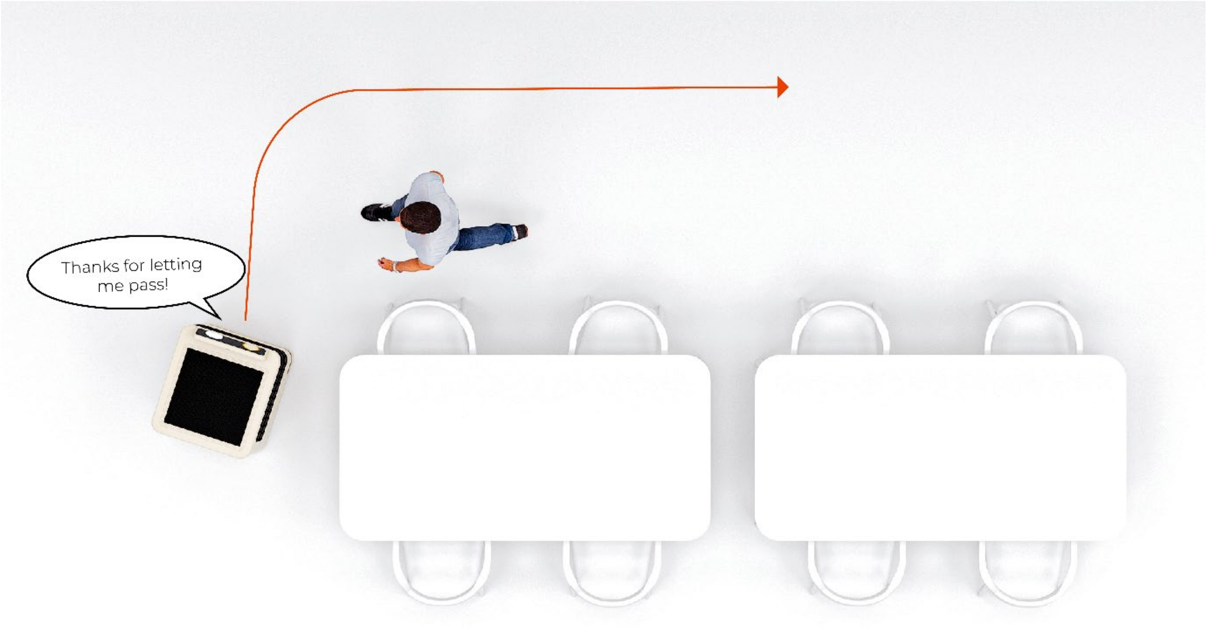

Figure 40 - Example of robot behaviour when exiting a corner, with a close distance between human and robot situation where the human stops.

After exiting a corner, the robot automatically aims to drive in the middle. Depending if a person is moving in the opposite direction the robot adjusts its behaviour depending on the distance to the person. If the person is relatively close to the robot after exiting the corner the robot will adjust its path to not intervene with the person (like when a person is at a relatively far distance when exiting a corner). However, if the person is relatively far away the robot will automatically position itself on the left-hand side in its driving direction. In any unclear situation, the robot automatically chooses the right side of the path to simulate a traffic situation.

In any situation where the robot feels it is being blocked by a person, it will utter the phrase "Excuse me, hot food coming through".

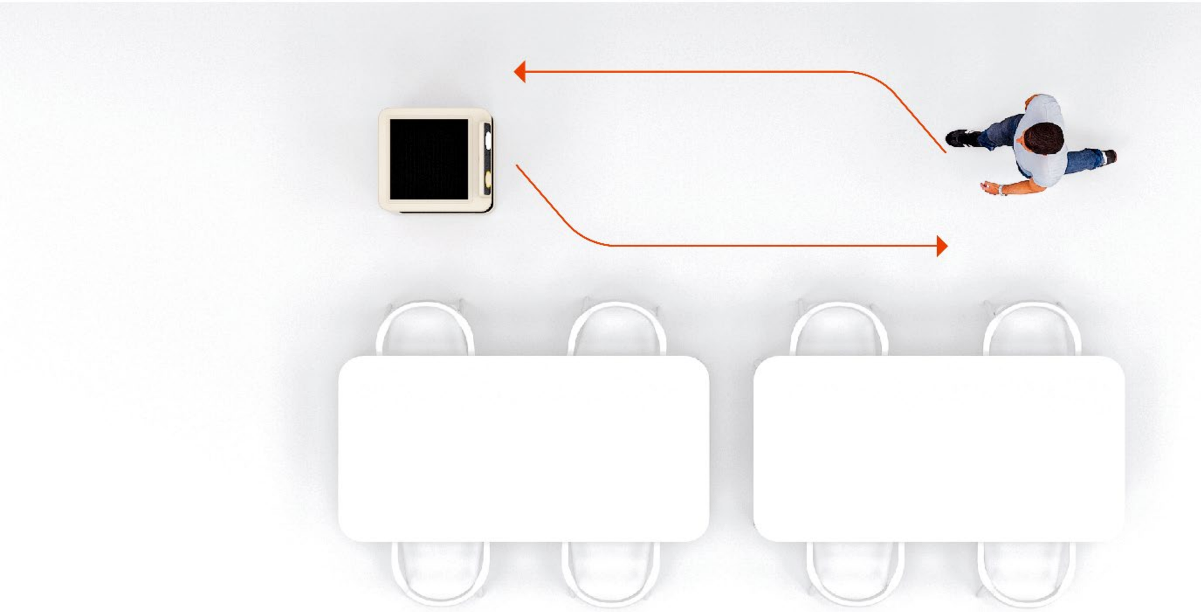

Figure 41 - Example of robot behaviour after exiting a corner, in a situation with a relatively far distance between.

Table 6 - Guidelines impacting the design of the movement.

Guidelines	Customer / Employee	Impact on design
The robot should have different behaviours depending on the urgency of the task.	Employee	The robot moves more aggressively when transporting food than when collecting dishes. To avoid obstructing people's pathways, the robot steps aside or stops more frequently when it is not delivering food.
The robot should be able to operate in busy situations.	Employee	The robot will keep on moving all the time, finding the best path possible while also using speech and sound to notify people that it coming through.
The robot should be able to operate after some furniture displacement.	Employee	By using a Bluetooth transceiver, the robot can locate a table's position, even though it has been displaced from its original position.
The robot should have an intuitive way of indicating movement.	Employee and Customer	The robot features indicators to show its trajectory but also makes distinct early movements when crossing paths with people.
The robot should take avoiding action/actions to not cause a collision.	Employee and Customer	The robot makes adjustments to people and stops in sudden "close calls".
The robot should be able to avoid getting in a position where it gets stuck.	Employee and Customer	The robot is able to drive backwards and identifies different objects to actively avoid getting in positions where it gets stuck.
The robot should adhere to norms of how similar technologies work in Sweden.	Employee and Customer	The robot by default tries to stay on the right side and has a type of emergency button that is quickly recognized.
The robot should have a non-disturbing level of communication.	Employee and Customer	The speakers of the robot make a "humming" sound, in varied volumes depending on direction.
There should be an indication that movement should be accessible.	Employee and Customer	Utilizing both sound and visual elements, the robot indicates movement and its presence to make it more perceptible for both the deaf and visually impaired.
It should be clear what the next action of the robot will be.	Employee and Customer	Using the integrated indicators, eyes and speakers, the robot can visualize or say its intended movement.
The robot interaction should have an appropriate level of perceived professionalism.	Customer	The robot, which features eyes and a humming sound while driving, does add a degree of playfulness to the robot. However, it does not display extreme emotions when provoking it, as that can be perceived as unprofessional.

Physical appearance

The basic shape of the physical appearance was very limited by the shelf arrangement, as form follows function was an essential identified theme in Scandinavian design. For this reason, the panelling of the robot remains as simple as possible, and in consideration of their functionality. The sectioning of the panels is designed to allow for easy access to crucial internal components and better repairability.

The boxy silhouette is set to create a stable appearance and a presence in the room. Additionally, the extendable storage compartment seemingly integrates with the robot platform to create further visual stability and a lower perceived centre of mass. A six-centimetre radius was incorporated into the outer corners to mitigate the perceived risk of sharper edges in case the robot encounters someone. The outside panels of the robot have a lighter colour to account for better visibility while also further contributing to a softer appearance. All surfaces that deviated from the outer box shape were assigned a darker colour for a consistent way of colouring the robot. This darker colour also creates a better contrast to most plates for the camera. Overall, the off-scaled appearance is set to reduce the impression of physical similarities to a human server.

Robot configurator

A robot configurator was also created, allowing restaurants to personalize their robots during procurement. This configurator would allow restaurants to select specific materials and colours of the robot's exterior panels, thus enabling them to create a robot that aligns with their desired profile. The robot configurator also allows customization of the shelf configurations based on the primary function of the robot. For instance, restaurants employing the robot primarily for beverage service can opt for additional self-balancing shelves. Furthermore, this facilitates the development of specialized shelves catering to specific restaurant needs. For example, for a pizza place, this would include a pizza rack. This modular approach enhances the robot's adaptability and caters to a wider range of restaurant types.

Figure 42 - How it could look when choosing a material in the robot configurator.

Table 7 - Guidelines impacting the design of the physical appearance.

Guidelines	Customer / Employee	Impact on design
The robot should be designed in a way that is inviting and perceived as friendly.	Customer	A generally friendly appearance has been achieved with the incorporation of rounded corners, light colours as well as friendly voices and eyes etcetera.
The appearance and perceived functional capabilities should match.	Customer	Active design decisions have been taken to avoid unnecessary anthropomorphic features that do not serve a purpose.
The robot's appearance should be able to be customized.	Employee and Customer	A robot configurator has been added, where colours and materials can be customized upon purchasing the robot.
The robot's physical appearance should be designed in a way that lowers the perceived risks.	Employee and Customer	The robot has been designed with large, rounded corners where a potential impact could happen, to make it be perceived as softer.
The robot should follow the values of Scandinavian Design.	Employee and Customer	The CMF has been strongly considered, as well as the following of the principle "form follows function".
The robot design should focus more on functionality than anthropomorphic features.	Employee and Customer	The functionality was never compromised for esthetical purposes.

5.2.2 Web Application

The 52 design guidelines that were a result of this master thesis, outlining how to design restaurant robots to operate and be accepted in a Swedish concept, as well as the design concept exemplifying them, were integrated into a dynamic web application. This is to make the otherwise difficult-to-navigate and less user-friendly experience easier and more enjoyable. The web application was built using Next.js (a React framework) and was delivered as "ready to be deployed" to the collaborating company. Some key features of the web application are:

- The main table area which consists of all the guidelines, one for each row. Each row consists of the guideline itself, but also the category, area of impact in the design, and which user it is relevant to.
- A search field to filter out rows based on specific keywords.
- Multiple attribute filters to sort out the guidelines currently relevant to the project. The filters available are the category, area of impact in the design, and which stakeholder it is relevant to.
- A modal (a pop-up requiring user interaction) will appear, containing a brief description of the impact on the example design concept along with a descriptive image. This modal can be triggered either by clicking on the row itself or by pressing the associated "Show Example" button.

5.3 Conclusion

Throughout the process of applying the design guidelines in practice, we noticed in retrospect that the work could be executed in a much more effective and efficient way simply by structuring it differently. Taking the agile approach (as described in *1.7 Process Overview*) in the "designing" phase of the master thesis had a lot of positives, as it allowed for quick iterations of the high abstraction level ideas to later be refined, but it also had negative consequences. One of the biggest issues was the lack of fundamental understanding of the bigger picture, as it was function and feature oriented. As previously highlighted in the insights presented in *4.2 Results,* restaurants are perceived by the users as a context in which the existence of tools (in the form of artefacts, such as technology e.g.) are limited, and instead are mostly driven by humans. Thus, the introduction of robots in the restaurant is seen as disruptive, as the service is seen to be transferred from the human to the robot (an artefact) instead. Working part by part, instead of deciding how everything should work together and contribute to create meaning for the users from the start, created a gap between the different components. This forced us designers to repeatedly backtrack the design process to address issues, rather than having a solid and meaningful concept from the start. For instance, when it was decided that a camera would be the best option for detecting if someone tried to steal food, we had to rethink how far apart the shelves required to be spaced out for the camera to get a good overview. As a result, we found ourselves unexpectedly pursuing to develop a design approach that could act as a support to the design guidelines, but also in the development of design concepts for robots that inherit the same characteristic of reallocating functions from a previous activity centred around a human to being centred around the robot.

6
Suggested Design Approach

This chapter will present a suggested design approach for Human-Robot Interaction (HRI) that was developed during the master thesis, including how it was developed, as well as the additional relevant theory. The suggested design approach is aimed to streamline the design process by providing a clear structure for the development of a service that has been previously centred around a human, into one centred around a robot.

6.1 Procedure

The suggested design approach was established by summarizing all the reflections that arose during the process of using the design guidelines in practice and identifying the key bottlenecks in the process.

In the discussion of all the reflections, it was noticed that a lot of the thoughts could be attributed to the existing models *Activity Theory,* and *The Fish Trap Model*, which have been well-established and validated by designers. Thus, instead of trying to reinvent the words, it was decided it would be beneficial to keep the core of these two different models and their terminology (as it has been proven to work and be understood by designers), and instead focus on suggesting how to apply them in the best possible way to resolve the issue of missing the broader scope.

As this suggested design approach can be seen as a result that was not intended from the beginning, a further review of existing literature was required that was not a part of the previous literature review. This is to get a better understanding of the existing models' core and more in-depth to see how they could be used together.

Finally, one last round of brainstorming was conducted on how the different parts could be fitted together, as well as what stages were required to make the models fit together as we intended. Therefore, the brainstorming was done by writing different suggestions and arranging them, in order to identify one sequence that was inline and described the summarized thoughts most accurately.

6.2 Result

The results include additional relevant theories to aid the reader's understanding, as well as the suggested design approach, both in an overview and in detail.

6.2.1 Introduction to Activity Theory and Fish Trap Model

To provide clarity for the upcoming parts of this chapter, this section will present our interpretation and the key concepts of activity theory and the fish trap model that was a result of the extended review of academic literature.

Activity Theory

Activity theory, which is rooted in the sociocultural tradition of Russian psychology (Chafi et al., 2021) is considered by some more of an analytical framework, than a scientific one and has been applied in a wide range of academic fields (Selvefors et al., 2023). Some of them have been proven to be helpful in Human-Computer interaction and industrial design (Desai, 2007).

The question is what the term *activity* in its name really is? From a larger perspective, an *activity* could be seen as an interaction between an actor and the world (Kaptelinin, 2014). Within the field of design, the actor is the intended user/users (and referred to in activity theory terms as the *subject*), and for each activity exists an *object* which is formed by motive(s) or need(s) (Selvefors et al., 2023). In a more specific sense, the "object" refers to the entity — whether mental or physical — toward which the individual's activity is directed (Cong-Lem, 2022). A central concept within activity theory is also the use of artefacts as *meditating tools*, which the intended subject utilizes to achieve their object.

Traditionally within practices related to design, such as HCI, the focus has been put on *what* and *how* users achieve their goals when breaking down a task into smaller bits for analytical purposes. However, the deeper understanding of *why* and *what* it means to the intended user(s) has previously been disregarded (Kaptelinin, 2014). This is what activity theory is meant to help answer. One way of visualizing and performing analytic work to form an understanding is the use of an activity system. When the user(s) gets involved in an activity, they perform related actions, which are constructed of operations. The understanding of an activity can thus be structured in a hierarchy consisting of three levels (with the activity at the top). See Figure 43 for an overview of the concept of breaking down an activity.

The second level (the action level) should describe what actions the intended individual user is required to perform as a part of the activity, and consequently to fulfil the object. This is driven by conscious goals which are supported by a specific artefact (tool). In the last level, the operations level, it should be clear what operations are required to fulfil the goal of the action. Operations are driven by conditions, which are in contrast with actions that are handled subconsciously. In other terms, operations are actions that have become routinized and are triggered by specific conditions. Thus, the characteristics of the individual are in focus, as well as the characteristics of the artefact (Selvefors et al., 2023). The three levels and their ingoing parts can be seen in Figure 44.

The last concept, which is important to be aware of when forming a basic understanding of activity theory, is that the hierarchy may transform due to *breakdowns*. Breakdowns are caused by *misfits* between the individual, the characteristics of the tool, and the conditions at the operations level (the opposite of this would be *fits*). This subsequently makes the user(s) transform operations back into conscious actions due to the focus being drawn to the artefact itself (Chafi et al., 2021; Selvefors et al., 2023). A well-functioning mediating tool with as few breakdowns as possible is therefore essential for user perception of the artefact.

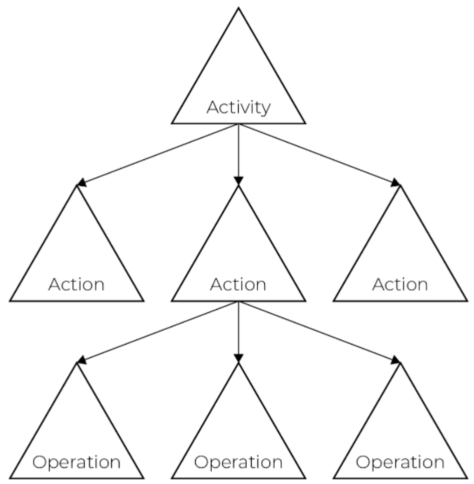

Figure 43 – Concept of the hierarchical structure of an activity system(redrawn from Kaptelinin, 2014).

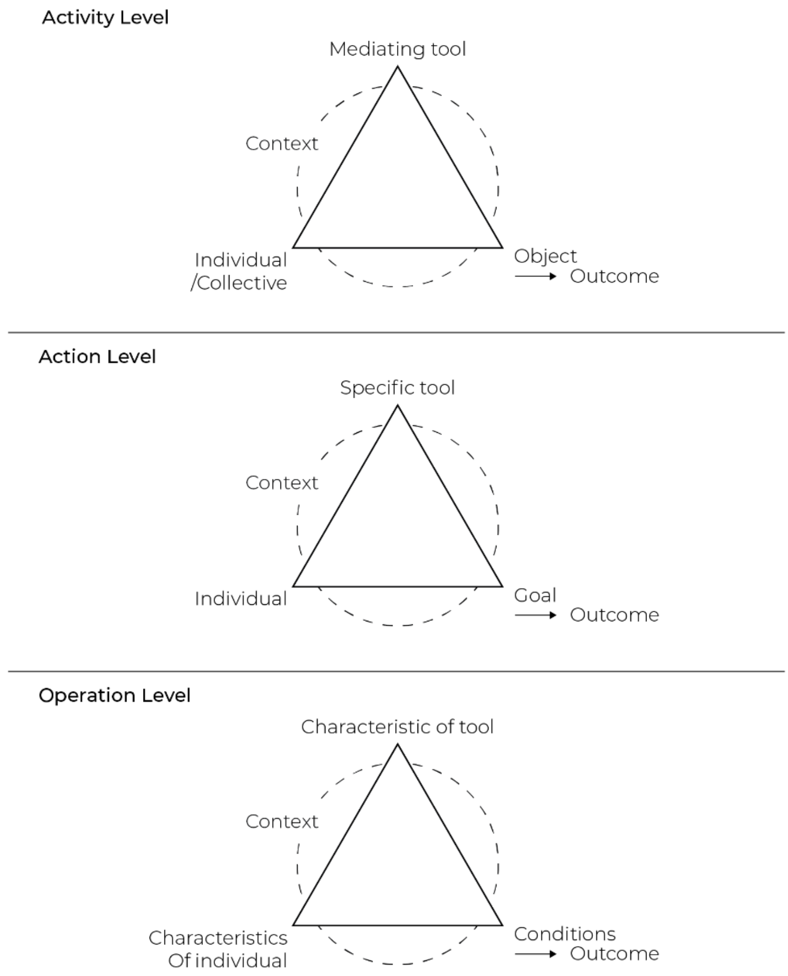

Figure 44 - The three levels of an activity system, and their ingoing parts (redrawn from Selvefors et al., 2023).

The Fish-trap Model

The Fish-trap model was originally created by Muller (2001), to help designers create form concepts of a product (as an artefact) up to, what he describes as, the *sketch plan* (a concept that fulfils its intended functions, and acts as a starting point for further refinement). As highlighted by the author, the model indicates how an artefact should be developed, making it prescriptive. A heavy focus in taking the fish-trap approach is on the exploration of the "design space", which implies that a large number of solutions/alternatives are generated throughout the process. Both these characteristics of the model help designers start the process of finding potential design alternatives and give direction to the project.

As seen in Figure 45, an overview of the Fish-trap model, the aim is to create a basic structure, structural concepts, formal concepts, and material concepts. This is done systematically through a converging and diverging process. Each phase goes through three steps:

1. Generate possible variants.
2. Cluster similar solution alternatives in categories (solution type).
3. Eliminate solution types that do not fulfil the specified selection criteria.

Each level of the Fish-trap can be described as follows (Muller, 2001):

- Basic structure: The basic structure consists of the functional components that are required for the artefact to fulfil its intended function.
- Structural concept: Structural concepts are solution types that have been generated by taking the basic structure, and spatially arranging the ingoing functional components in different configurations (thus generating topological variants).
- Formal concept: Formal concepts are solution types that have been generated by taking the structural concepts and making a first overall materialisation/embodiment of them (this implies the type of form and material are attributed to the structures, as well as how everything should be connected). The generated variants before categorization are referred to as typological variants.
- Material concept: Material concepts are solution types that have been generated by taking the formal concepts, and through combining insights from the earlier phases further work on materialisation to refine them. This includes exploring aspects such as colour, material, finish (CMF), textures, manufacturing methods etc. The generated variants before categorization are referred to as morphological variants.

An inherent tool to the Fish-trap model is the use of sketching for representing the ideas, as visualization is considered a central part of this method (Muller, 2001). However, there could be other available tools to the designer, as for example mock-ups, that are better for certain situations. The most important thing is that the tool should allow the designer to efficiently and effectively explore as many variants as possible to ensure that the design space is sufficiently explored. Lastly, the visualizations will, according to Muller, need to become progressively more detailed, and therefore in the later phases require more time. The designer will therefore need to be more selective in which concepts to develop.

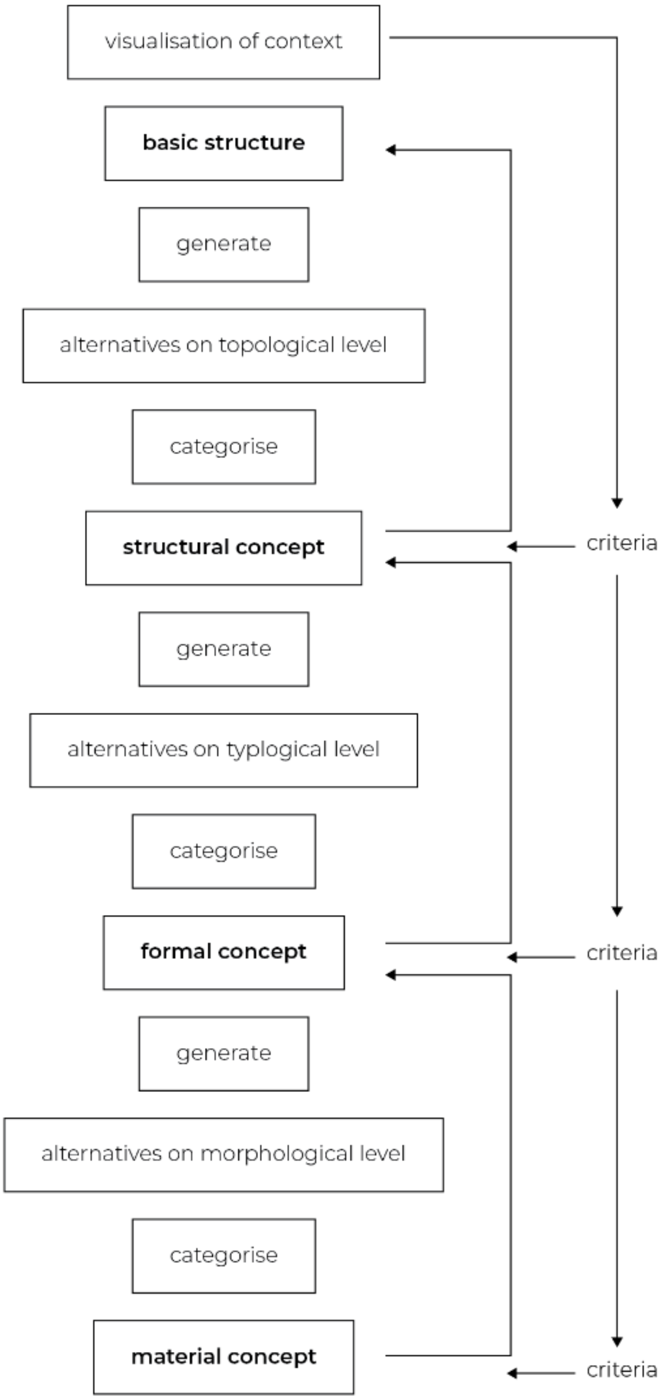

Figure 45 - Overview of the Fish-Trap Model (redrawn from Muller, 2001).

6.2.2 Overview of the Suggested Design Approach

The suggested approach, which is visualized in Figure 46, is a systematic process that is built upon divergence and convergence, where the generated solutions' embodiments are continuously increasing in fidelity with the progression of each phase. The goal of the suggested design approach is to enhance the efficiency of the design process by establishing a structured framework for transitioning a service, originally centred around a human, to one centred around a robot. It prompts designers to adopt a broader perspective on human-robot interaction (HRI) and encourages them to generate an overall working concept from the beginning, without getting too deep into the details first.

The proposed approach can be segmented into six primary phases. Two of the phases are directly drawing from the terminology and essence of Activity Theory and The Fish Trap Model (which can be seen in Figure 46). These six main phases of the suggested design approach are:

1. Deciding primary selection criteria.
2. Mapping out the desired HRI by activities, actions, and operations.
3. Decide on the functional components (basic structure).
4. Deciding secondary selection criteria.
5. Generate structural, formal, and morphological solutions by going through The Fish Trap.
6. Validating the concepts.

Important to notice is that despite the seemingly linear systematic workflow that the converging and diverging phases of the suggested design approach are promoting, it is still allowed and encouraged with iteration. New insights are not uncommon to turn up when imagining the different possible interactions and scenarios, and thus concepts that have been previously considered lacking in potential might require to be reevaluated. A new round may be beneficial to perform by going through the structural, formal, and morphological solutions once more. Therefore, documentation throughout the suggested design approach is an essential theme, to understand why certain decisions have previously been made.

Why Activities, Actions & Operations (Activity Theory)?

As previously stated, it was noticed during discussions related to the interactions and how these were transformed from a service centred around a human, with limited perceived use of tools, to a more automated service based around a robot, often ending up in terms found in Activity Theory. Therefore, instead of trying to invent new terminology, we suggest mapping out the different activities, actions, and operations with the help of the basics of activity theory.

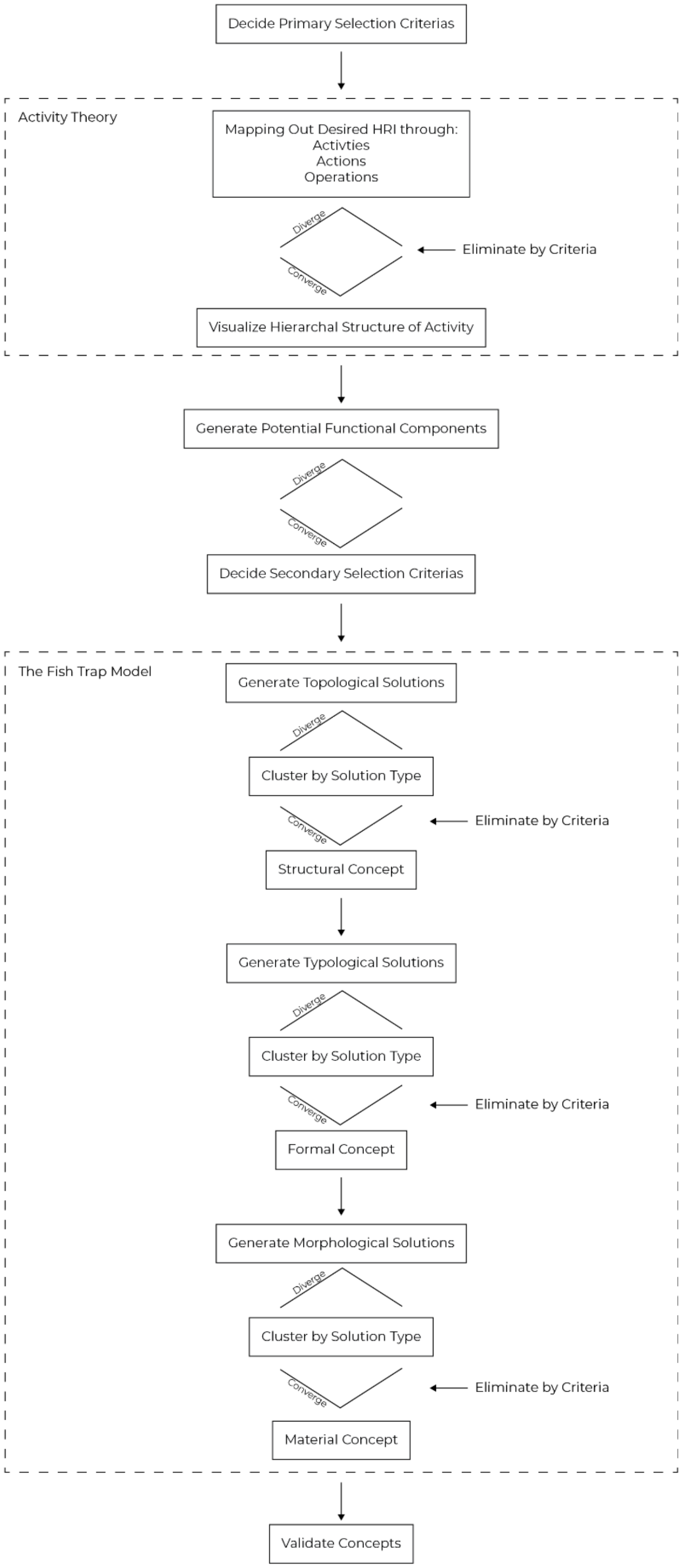

Figure 46 - Overview of the suggested approach.

6.2.3 Detailed Description of the Suggested Design Approach

As this suggested approach aims to create a design concept that creates meaning for the user and is accepted over a longer time frame, activity theory is suitable, as this is a framework that tries to answer these types of questions. This is in contrast to other task analysis methods, such as Hierarchical Task Analysis. These methods often include much more descriptive steps that need to be taken to accomplish the different goals. The issue that arises, which was discovered during the design process, is in situations that are difficult to break down into individual goals, making the task analysis seem incomplete, or generally lacking in detail. With that being stated, task analysis will most likely be required in later stages, however, this suggested approach aims to create an overall design concept that can embody the desired interactions which create meaning for intended users.

Stage 1 – Deciding Primary Selection Criteria

In the first step, there is a need to determine clear selection criteria which are not dependent on any specific components. These are supposed to assist the designers as they progress throughout each stage, helping them discard solutions that do not align with the project's objectives or contribute to the final concept.

Example

In the case of designing a restaurant robot, the selection criteria could be the design guidelines presented earlier (for example, *the robot should inform employees in case of incidents or malfunctions in order to resolve them quickly*). However, it could also be other factors such as available manufacturing methods, brand-specific values etc.

Stage 2 – Mapping Out the Desired HRI

To have a good basis for designing the robot, there is a need to establish what desired interactions should exist between the human and robot to support the service process. This is done by thinking through scenarios that may occur between the intended user and robot, to think out all the possible interaction points.

To break down the desired human-robot interaction, it is beneficial to break down the desired behaviour between the human and the robot into a hierarchical structure with activities, actions, and operations. What fidelity the hierarchy ends up in is up to the designers, however with the help of it should be possible to answer *WHAT, WHY, and HOW* the intended user should execute the activity.

Example

This is only an example of one activity with one associated action and operation. In a real scenario, this activity system will be much more intricate and detailed (i.e. each activity will have many more actions with many more associated operations).

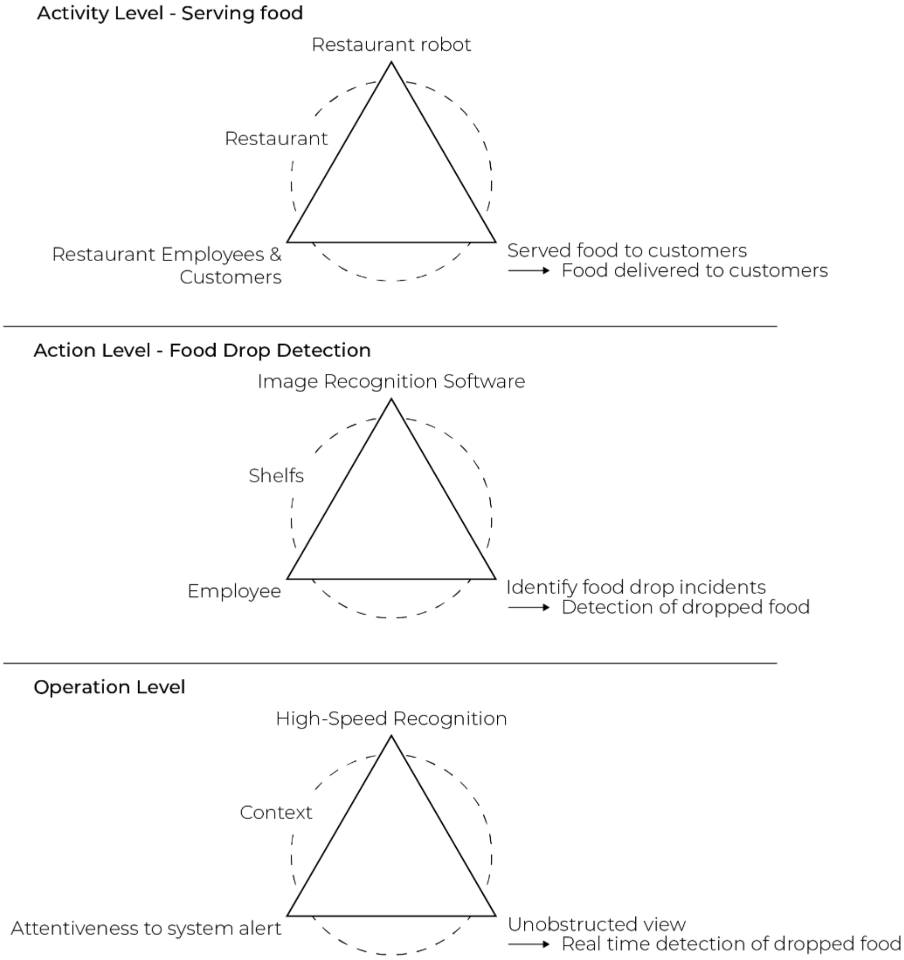

Figure 47 - Example of one activity system (redrawn from Selvefors et al., 2023).

Stage 3 – Deciding Functional Components

Taking the previously decided activity system (consisting of a hierarchical structure of activities, actions, and operations), an ideation session to come up with characteristics of the robot (that can support the operations, action, and finally the activities) is to be performed. Ultimately, these characteristics are to be translated into functional components that can inherit these characteristics. Deciding the functional components is suggested to be done in a four-step process. The parts can vary in fidelity and be both tangible and intangible. It's up to the designer to decide their level of detail.

1. Generate ideas on how to create fits between characteristics within the activity system.
2. Group the different solutions by similarity.
3. Walk through the activity diagrams to discard those solutions that cause breakdowns.
4. Define the solutions as functional components (that are to be used as building blocks for later use).

In addition to the functional components that are decided through the four-step process, there may exist some functional components that are required for functional reasons (but is not associated with any particular action). These should also be included in this stage.

Example
An example from the previous example of the operation *Food Drop Detection,* one component that would solve this (and was the chosen approach in the design concept presented in this master thesis) is the use of a camera. This camera in combination with object detection (machine learning) would be able to detect that the food has been safely removed.

Stage 4 – Deciding Secondary Selection Criteria

After deciding on the basic structure of the concept, there may exist a need to add new selection criteria that have become relevant due to the selected functional components. Therefore, it is highly beneficial to review the previously determined selection criteria and question if there is a need for additional new criteria. This stage is thought to ensure that the selection criteria remain helpful, as well as to adapt to the evolving needs that often come with design projects.

Example
Taking the previously decided camera that would be used for surveillance of the food (ensure that the food has been taken when arriving at the table), then a selection criterion of its field of view could be relevant to add.

Stage 5 – Generate Structural, Formal, and Morphological Solutions

In this stage, which is fully attributed to The Fish Trap model and its author Wim Muller, the focus is put on the embodiment of the robot. The difference between our view (that should be taken if applying this suggested approach), and Muller's, is the shift in perspective from having visual aspects in primary focus (and function more as an afterthought), to instead putting function in the spotlight. However, the same terminology (and structure) is used. The same sequence of steps that is taken at each level is:

1. Generate possible variants.
2. Cluster similar solution alternatives in categories (solution type).
3. Eliminate solution types that do not fulfil the specified selection criteria.

Topological Level Ending in Structural Concepts

The aim of the topological level is to create structural concepts of the previously decided functional components. At this level, the focus should be on generating variants that differ in topology (spatial order of the components). The exploration in the diverging stages should be done freely without too much afterthought (thus ensuring every possible configuration is tested). When evaluating the different structural solution types, it is important to place the different structural solutions in their context, thus imaging possible interaction with the user in question. This may result in new possibilities that the HRI is executed.

Example
The cameras' relation to the food can be explored, to ensure that its placement is not hindered by any other component. Structural concepts would involve side-mounted cameras, top-mounted cameras etc.

Typological Level Ending in Formal Concept

In the next phase, the first real materialization begins, essentially meaning that the global form and its material are attributed to the previously generated structural concepts. Similarly, as in the topological level, in the divergence phase, the ideation should be done freely without too much intention to the selection criteria to ensure that the solution space is fully explored.

However, in the converging stage, their potential for realization should be evaluated against the selection criteria, and similar solutions are clustered into solution types. The most promising solution types can be further developed in detail into formal concepts in which the intended interactions should be clearly presented.

Example

The type of camera, its size and form, and specifically how it is incorporated into the other elements can be explored. For example, taking the previous camera placements from the structural concepts it might be refined to integrate seamlessly a sleek, modern shell or prominently featured for easier maintenance.

Morphological Level Ending in Material Concept

In the last phase of the fish trap, the formal concepts are to be further materialized and refined, meaning combining previously gained insights. Even though the general characteristics have already been set in the previous phases, there are still a lot of details that need to be investigated and questions need to be answered. Muller noted in the original fish trap model that this does not mean changing previously constructed concepts in their entirety but rather tweaking them through materialisation. This implies a further exploration should focus on the colours, material, and finishes (CMF), as well as how possible manufacturing and assembly processes are to be performed. When the divergence in this phase has been performed by iteratively doing this process, there is time for convergence by clustering similar solutions (from a technical standpoint, but also possible interactions by the intended user).

Example

The colour, material, and finishes of the panels embodying the robot can be explored to see if they change the visual impact and perception of the design. Continuing with the camera example, it might be chosen a colour and material for the surface it points to ensure a good contrast for plate recognition.

Stage 6 – Validating the Concepts

Once the material concepts have been developed, it is important to do one last elimination process of the complete solutions from the selection criteria to ensure that they fulfil all requirements. This is done by going through the selection criteria one by one, and if one does not live up to the standard, reject it or alternatively suggest changes that need to be done. Once the theoretical elimination has been performed, there should be at least one feasible concept that is ready to be further elaborated upon. However, a good foundation for other parts of the full product development process should now have been established, and according to Muller, both primary and secondary functions should have been fulfilled while working through the fish trap model.

Final Note

The final concept(s) should preferably undergo further evaluation with the intended users, as there can always be scenarios and behaviours that are difficult to predict. Lastly, as previously highlighted, this design approach will most certainly not capture all behavioural aspects or details of every interaction (as it is not the aim of it). However, the preconditions and a solid design should now exist and can be further refined in detail (e.g. by specifying the exact steps required to navigate through a UI in the display).

6.3 Conclusion

The suggested design approach, which was based on the insights gained during the process of applying the design guidelines in practice, and a review of the existing literature on activity theory and the fish trap model, is believed to help designers in the future who want to design robots similar to the restaurant robot in the sense that an activity that previously has (or has been perceived) centred around a human, both now centre around a robot instead.

To see if the suggested design approach would be understood by designers, and support them in their process, the suggested design approach would benefit from being evaluated. Therefore, it was agreed that it should be added to the evaluation phase, to get insights from designers who have experience working with HRI, and similar application areas.

7
Evaluation

This chapter presents the insights that were gained from the evaluation of design guidelines and the suggested design approach, which was done through a focus group. The chapter starts with a description of the focus group was conducted, and the results in the form of both positives and possible improvements that could be made. Lastly, it concludes what could be done to improve both the design guidelines and the suggested design approach.

7.1 Procedure

The focus group session was conducted to identify potential flaws, as well as other considerations to the design guidelines and the suggested design approach that resulted from this master thesis. In preparation for the focus group session, the participants, who were two designers experienced in HRI, were provided with a document containing solely the design guidelines, and which user they intended to target. They were provided instructions to review the document and highlight any design guideline they found either confusing, felt needed further clarification, or was seen as unnecessary.

The session itself began by asking the participants to give their initial impressions of the design guidelines. Thereafter, a more in-depth discussion took place where the participants were asked to revisit and elaborate on any sections they had highlighted during their review of the document. The participating designers were then presented with the suggested design approach, as well as a brief walkthrough of its aim, the different steps involved, as well as how it was intended to be used. Once again, they were asked to provide feedback and critique of the suggested design approach and discuss how they thought it could help the design process of service robots in general, as well as how it could be elaborated.

7.2 Result

The focus group session provided new insights into how the results could be further refined to better facilitate a design process. This section is divided into results for the design guidelines, and suggested approach.

7.2.1 Design Guidelines

The initial discussion of the guidelines gave some important insights into how the design guidelines were interpreted from a designer's perspective who had not been actively involved in the project. There were several guidelines identified that according to them required further clarification. It was also highlighted that a few guidelines would benefit from being broken down into multiple guidelines and further contextualized. However, overall, the participants found that the guidelines had good coverage of the most important areas that are to be considered when building a robot. They also stated that most of the design guidelines were clear, and they could see benefiting from them if they were to apply them in practice.

One additional thing, that was not a part of the aim of the master thesis, but brought up by the participating designers, was that many of the design guidelines most likely could apply to other robot design contexts. Therefore, it was suggested to further define which guidelines were more universally applicable, and which were more specified for the restaurant context.

Furthermore, initially, the participants of the focus group would like to see a prioritization of design guidelines, as they thought it could potentially make the work for the designer more efficient (as they then could know where to put more effort and time into the work). While acknowledging the potential benefits of prioritization, we discovered during our design process that the broad nature of the guidelines meant they could be applied to a wide range of components of the robots. Consequently, the actual significance of a guideline could vary depending on multiple factors, rendering prioritization challenging.

Lastly, the time sensitivity aspect of the design guidelines was discussed since they were developed based on the *current* (2024) acceptance. It was agreed that many of the design guidelines focused on different levels of interactions rather than the actual inherent functionality it was believed that they had some reliance on time and could be adapted to foreseeable technological advancements. However, this is something that would require further exploration.

7.2.2 Suggested Design Approach

Overall, the combination of activity theory and a more function-focused fish trap model was seen as a good way of structuring robot design processes in general. They thought it was an interesting approach that had potential for the development of robots, such as restaurant robots.

One consideration mentioned regarding the usage of the fish-trap terminology was that it is not the best model for capturing the specific behavioural aspects of the robot in a design process. However, we argued that the usage of activity theory in stage two of the approach could be used to capture the behavioural aspects from a human-robot interaction point of view. Further, the suggested design approach was never meant to address the intricate specifics, such as the precise sequence of operations while navigating a UI. Instead, its aim was to underscore the importance of establishing functional components that could possibly inherit the intended behavioural capabilities, which could later serve as the focal point for refinement, while initially prioritizing the broader perspective. For instance, in the case of the example concept developed in this master thesis, one such component could be the display with eyes (as the precise movements might not be possible to be detailed through this process). It was discussed that this may would be required to be further emphasized in the suggested design approach's description and figure, to be clear what the aim is.

7.3 Conclusion

Overall, both the design guidelines and the suggested design approach have been validated, by two designers experienced in working with HRI, to fulfil their intended purpose.

For the design guidelines, it was suggested to clarify and break down a few guidelines into multiple ones. With this feedback, the design guidelines were gone through one last time, which were added to the final design guidelines which could be found in the Appendices, as well as the web application (previously presented in *5.2.2 Web Application*).

For the suggested design approach, it was agreed among the participants and us to clarify its purpose, to not be misunderstood for digging too much into the details, and rather focus on the larger picture. It was never intended to capture all the details, but rather to zoom out and create a fundamental concept that has the possibility for further refinement and development of more intricate details.

8
Discussion

This chapter will present a discussion of the master thesis. It will start with the contributions made in relation to the research questions, followed by a general discussion of the topic of acceptance of restaurant robots within a Swedish context. Subsequently, the chosen methodology and process will be discussed. Furthermore, suggestions on future work for the continuous development of robots in a restaurant context will be made. Finally, the chapter ends with the ethical and sustainable considerations that were addressed throughout the master thesis.

8.1 Research Questions

In this part of the chapter, the research questions are repeated and discussed how, and to what degree they have been answered throughout the master thesis.

8.1.1 Research Question 1

> *What are the specific needs and requirements of users (dining customers and restaurant employees) in a Swedish restaurant setting, for a successful implementation of hospitality robots*?

During the master thesis, an extensive literature study, as well as qualitative research in the form of user studies and observations, was made to understand users' needs and requirements, as well as presented. The qualitative research was done through 22 interviews, and three observations, which provided data that could be synthesized with the help of KJ-analysis. In conjunction with the knowledge gained from the literature review, a lot of insights regarding the specific needs and requirements of the users, mainly associated with acceptance, were gained, and presented in the chapter *4 User Research*. These insights would later act as a foundation to be able to answer the rest of the research questions. A few examples of these insights are the need to interact with a human when ordering to be able to ask questions, the need to deliver food quickly to ensure adequate temperature, having anthropomorphic features that fulfil a purpose and are at an appropriate level, and the need to create a unique experience for the customers that fit with the restaurant's desired profiles.

We believe that this research question has been answered to the full extent. It is, as highlighted in *4.2.1 Insights - User Interviews*, a highly complex topic with a lot of factors, and sometimes contradicting opinions, and not every single one could be brought up in this master thesis. However, we conclude that the most important insights that have had the biggest impact on the acceptance have been brought forward. However, we also conclude that these needs and requirements most probably will change in the future, as acceptance is a time-sensitive phenomenon.

8.1.2 Research Question 2

> *What design guidelines can these needs and requirements from users be translated into, which can act as support for designers creating a robot that is to be accepted in a Swedish restaurant setting?*

In the end, 52 design guidelines were developed to aid designers in creating restaurant robots that are to be accepted by both dining customers and restaurant employees. These design guidelines are divided into four different categories (Appearance, Function, Interaction, and Desired Result of Impact), as well as indicating which type of user is primarily affected by it.

The design guidelines, which can be seen as a product of all the insights gained from the intended users' needs and requirements, were translated and iteratively developed by applying them in practice. To facilitate the use of the design guidelines, they were packaged through a website to be delivered to the collaborating company of the master thesis (can be read more about in *5.2.2 Web Application*). However, they can also be read in

Appendix A – Design Guidelines. These resulting design guidelines were validated to give support in the development of robots, through a focus group consisting of designers experienced in working with HRI. Therefore, we argue that the research question has been answered.

8.1.3 Research Question 3

> *How can these design guidelines be embodied in a design concept, to provide user acceptance?*

In this master thesis, a robot concept was created to exemplify how the design guidelines could be applied, in order to create acceptance from both dining customers and restaurant employees. The design features three stationary shelves, one self-balancing tray, a drawer for storing necessities during servings, a display for employee inputs, virtual eyes for facilitating interactions, and much more. These features have been encapsulated with the principal *form follows function* and other Scandinavian design values. In the chapter, *5 Designing and Refining*, a full description of the design concept could be found.

The design concept was developed using the design guidelines, and their impact on the result was clearly documented. This has been considered to provide a good picture of the purpose of the different guidelines, and in our opinion answer the research question of how they can be embodied to create acceptance. To be noted, even though the design guidelines were evaluated in conjunction with experienced designers of HRI, the design concept itself was not validated by the end users, due to resource limitations and other practical implications. Therefore, the design concept itself has not been proven to provide user acceptance, but as it is a byproduct of the design guidelines it does in theory provide a level of acceptance.

8.2 General Discussion

As previously highlighted in the results of the user studies, in combination with the knowledge gained from the literature review, designing a restaurant robot to be accepted within a Swedish context is a complex and intricate endeavour. This is mainly due to it being heavily context-based. In some contexts, the robots available on the Swedish market already provide sufficient acceptability among the customers to be adopted, and from the organizations' side are seen as a good marketing tool to bring in more guests to their restaurant. The employees who were experienced in working with robots did however shed light on the practical limitations of these robots, making them not sufficiently useful to replace humans or assist the employees in busier situations. However, due to it being voluntary in what degree to use the robot, interviewees who are experienced of working with robots stated that they accepted them to be at their workplace.

Due to its limited usefulness for the employees, it does not solve the bigger problem of the staff shortage presented in the introduction. As presented in the insights of the interviews, people do not want to fully automate a lot of operations, such as taking orders, and therefore the need for human staff still exists. People experienced with working with robots also said that there has never been one time where they have been able to replace a human, and instead, they have only been there as an extra tool to assist in heavy lifting (making it an extra cost for the restaurant). This in conjunction with people expecting to pay less for the service due to it being perceived as a cost-saving tool that provides lesser service, creates an impossible equation to solve. In other words, the basis for acceptance of restaurant robots in Sweden may not exist yet, until customers' perception of robots being able to provide a better experience changes.

Lastly, even though we believe that the developed design guidelines are the best option to follow in order to fulfil the needs and requirements of the intended users to create acceptance towards the robot, it is still questionable if it would be created over a longer period. As found in the interviews with customers, many stated that it would be fun to try out once, but still had a hard time imagining they would not miss the human touch. This is something that needs to be further investigated and a part that is missing from the master thesis, as it would require to follow (mainly) customers over time and see how the acceptance changes with experience.

8.3 Methodology and Process

The initial part of this master thesis, the emphasize phase, was very workload heavy. This as answering the research questions required a more comprehensive exploration of the existing academic literature, as well as a thorough user study (including both interviews and observations) initially imagined. However, both offered valuable insights into the specific needs and requirements, which could be translated into design guidelines for successfully implementing a restaurant robot in a Swedish context. In addition, the selected acceptance models in the literature review that acted as a foundation for the interview questions and forming an understanding of acceptance proved to be very helpful. Many of the insights aligned and could be explained with these models, and the only element missing from the AIDUA model is the perceived value of the service. Finally, the thing that could be argued as lacking from the empathize phase of the master thesis would be a wider span of restaurant types, as well as different robots for observations. In this project, only one type of robot within one given context could be the subject of the observations, as there were not any other open restaurants, with restaurant robots, within a reasonable travel distance (due to the fact that restaurant robots have not been widely adopted yet).

The subsequent phase, the ideation phase, which applied an agile approach by first developing high abstraction level concepts, and using sprints to refine these ideas iteratively, was proven to be very beneficial. This as it allowed us as designers to apply a wide range of tools and to explore the different aspects of the robot more freely, to gain new insights into the process of designing restaurant robots, in the form of challenges and potentials. Subsequently, this allowed for the design guidelines to continuously be questioned by us as designers and further refined, either when they were difficult to interpret or did not provide any actual support to the design process. However, as has been previously highlighted in the chapter *Suggested Design Approach*, the work could be structured more effectively and efficiently developing a design concept of a robot that provides acceptance over a longer period. This concern is considered addressed by the introduction of the suggested approach, which would provide structure and guidance throughout the design process, encouraging the designer to step back and reconsider the activity and meaning first. This is when a service is going from being perceived as being fully centred around a human, to being more centred around the robot (the design) itself.

Due to the master thesis being research-heavy in order to answer the research questions, a lot of the available time for the full project required to be allocated to the beginning of the project. This is due to user studies being a time-consuming process with the inclusion of planning, recruiting participants, and executing the observations and interviews themselves, but also the analysis which included transcribing, reading, and listening everything through, as well as performing the KJ-analysis and summarizing the findings. This led to the project needing to "sacrifice" time in the later stages of the master thesis, which meant that the initially planned, and more extensive validation was not possible to complete. However, as the aim of the master thesis was to create the best possible guidelines (not the best possible robot), as well as an embodiment that would exemplify how they could be used, we believe that this has been fulfilled, meaning that we were comfortable with abandoning this plan. With that being said, there was a validation step involved as previously outlined. The validation stage was conducted through a focus group comprising of designers with significant experience in Human-Robot Interaction (HRI). Their valuable insights were deemed a practical approach given the available resources and prevailing conditions at the time. Nevertheless, we acknowledge the fact that it would have been more beneficial to observe and assess the applicability of these insights through a more extensive evaluation as well.

8.4 Future Recommendations

To achieve a good integration of restaurant robots in the Swedish context, we believe that there is a need for further research and exploration of the topic. Therefore, with the insights gained from this master thesis, we would like to propose four different directions for future work in advancing robots to be used in restaurants within Swedish contexts. These are: Exploring the organizational effects of the integration of the robots, taking a business-oriented approach on the topic of restaurant robots, applying, and potentially developing, the presented suggested approach, and lastly developing a fully functional prototype to be used within real restaurant settings.

Organizational effects

In this project, it was decided to narrow the scope of the user studies to the customers and employees who will be working directly with the robot every day, as the timeframe otherwise would not be reasonable. With that being said, as highlighted in the interaction diagrams in the chapter *Literature review*, the organization into which the robot will be integrated would have an effect. For instance, if the organization involves their employees in the discussions of acquiring a robot, and how it then should be used. Indications of this were also present in the user studies, with topics such as adequate training, the voluntariness factor, and employers' intentions of procuring the robot having an effect. Therefore, we believe this is crucial to further investigate.

Business-oriented approach

During the interviews (mainly those conducted with customers), the value of the service in relation to price was brought up multiple times, and many opinions regarding this aspect were indicated to exist. Since the master thesis was oriented towards findings needs and requirements from users that could be translated into design guidelines, as our expertise is within the field of design and not business, this was not considered extensively. However, we note that this has a great impact and therefore taking a business-oriented approach to the exploration of the market would be beneficial.

Applying the suggested design approach

In this master thesis, a design approach for HRI was suggested and validated by experts through a focus group. However, as previously mentioned, it was not applied in practice. Therefore, we suggest future designers try applying the suggested design approach to develop robots within services that previously surrounded a human, but with the intention to move some or all of the responsibility to the robot itself. We encourage those designers to find limitations with the approach and suggest changes accordingly.

Robots in a real situation

Due to resource constraints within the project, the design concept could not be prototyped and undergo testing in a real restaurant context to identify potential limitations. Consequently, we propose further research to develop and assess a robot tailored specifically for the Swedish context. This robot could be created using the recommended methodology in tandem with the design guidelines, or borrow design elements from the concept, or the whole design concept, presented in this master's thesis.

8.5 Ethical & Sustainability Considerations

In this master thesis, several ethical considerations could be made concerning the topic of restaurant robots. Thus, in this section, a selection of the considerations we have found most important to highlight is presented.

8.5.1 Ethical Considerations

By implementing a restaurant robot, one ethical consideration to acknowledge may be the loss of some job opportunities. Despite one of the arguments for introducing restaurant robots being to handle the current labour shortages, there is potentially a loss of service jobs that require little to no education. However, at the same time comes a potential increase in jobs surrounding the maintenance and development of robots. These new jobs might require a higher education. As seen in this master thesis, the robots would not currently be able to replace any employee, however as the technology develops, and the foundation for acceptance changes, this will be important to acknowledge.

One other ethical consideration that was kept in mind during the whole master thesis, is the existence of people with various disabilities. If the robot is not designed with their needs in mind, they may face challenges when interacting with the robot. Therefore, it's important to find solutions to minimize accessibility-related issues (such as having sound, to indicate the robot's presence, even for those with impaired vision etc.).

As the resulting robot concept of this master thesis makes use of machine learning (for object detection etc.), it is important to acknowledge that these algorithms may contain biases towards gender and ethnicity etc. As the development of the algorithms progresses these will most certainly become less, but it's important to monitor these in a transparent fashion and make use of them in a responsible fashion. One other consequence of using machine learning is the data collection and surveillance that is inevitable. Customers and employees may not be fully aware of how these algorithms work and the implications they may have when interacting with robots. It's therefore important to maintain transparency of how the data may be used and stored, as well as carefully considering when it is a necessity and contributes to something important.

Lastly, in relation to the user research phase it has been important to maintain full transparency in how the study's results were to be handled and used. Data obtained from individuals who participated in user research were handled in accordance with ethical principles and data protection regulations.

8.5.2 Sustainability considerations

From an ecological sustainability perspective, the production of new restaurant robots will require material resource usage. The question is if this resource usage could be justified, as the robots today will not be able to solve the bigger problem of labour shortage (due to their inability to replace a human). Furthermore, since the current acceptance of robots is likely short-term, primarily driven by initial hedonic motivations, it is essential to devise strategies to ensure long-term acceptance, to ensure that the utilization of robots justifies the material resources invested. Lastly, since a restaurant robot is a product driven by technology, it is reasonable to argue that new technological advancements will continuously be introduced. To enable the implementation of new technologies some aspects of modularity should be and were introduced for the robot concept, to be able to stay up to date. With this also comes the aspects such as easy service and repairs.

Lastly, one factor that is important, and not to be forgotten, is the social sustainability aspect of dining at a restaurant. The implementation of restaurant robots on a bigger scale could in the future generate a loss in Human-to-Human interactions that could lead to some individuals losing a vital social element. As of now though, the robot will not impact what customers and employees expressed as valuable and meaningful connections.

9
Conclusion

Today's existing restaurant robots are not adapted for the Swedish context and have not been widely adopted. The master's thesis, which was aimed at establishing design guidelines for a restaurant robot to be accepted within a Swedish context, adopted a wide range of different methods and investigated the topic with a Research through Design approach. As a result, 52 design guidelines were developed from insights acquired from the literature review, as well as the intended users' needs and requirements. These design guidelines are divided into four different categories, *Appearance, Function, Interaction,* and *Desired Results of Implementation*, and can be found in the Appendices of this master thesis. They were also integrated into a web application to assist the use of them.

Alongside the design guidelines, a design concept exemplifying a potential embodiment of these guidelines was created. This was achieved by applying the design guidelines in practice, with the aim of refining them based on insights gained during the development of a design concept of a robot that was to be accepted. The design concept itself consists of three stationary shelves, one self-balancing tray, a display for employee and customer interactions, virtual eyes for facilitating interactions, and an appearance that adheres to the principle of form follows function, as well as other Scandinavian design values. As the design concept could not be realized and tested, there are still some question marks if the design concept of the robot would be accepted by both customers and employees in a real setting. However, according to the guidelines, which were based on customers' and employees' needs and requirements, this would be one of the more prominent solutions.

Furthermore, the Research through Design approach in the project had an unanticipated outcome, in the form of a suggested design approach, encompassing terminology and essence of activity theory and the fish trap model. It can be described as a six-step process, which are *deciding primary selection criteria, mapping out the desired HRI by activities, actions, and operations, deciding on the functional components (basic structure), deciding secondary selection criteria, generating structural, formal, and morphological solutions by going through The Fish Trap, and validating the outcoming solutions*. The suggested design approach could in a structured, efficient, and effective way be used to develop a meaningful and purposeful concept of a robot that is meant for a context and activity, that has previously been perceived by users to be centred around a human, with a low involvement of tools (in the form of artefacts) such as a restaurant robot. This suggested design approach was evaluated with two external designers experienced in working with HRI, which confirmed that it could be a beneficial way of working. In addition, the suggested design approach could be further refined with the insights acquired from the discussion.

We hope that these results and insights gained from the master thesis could help designers in the development of restaurant robots for the Swedish Context, and or other types of HRI using the suggested design approach.

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Appendices

Appendix A – Design Guidelines

Appearance

1. The robot should be designed in a way that is inviting and perceived as friendly.
   - Applicable to: Customer.
2. The appearance and perceived functional capabilities should match.
   - Applicable to: Customer
3. The robot's appearance should be able to be customized.
   - Applicable to: Employee and Customer.
4. The robot's physical appearance should be designed in a way that lowers the perceived risks.
   - Applicable to: Employee and Customer.
5. The robot should follow the values of Scandinavian Design.
   - Applicable to: Employee and Customer.
6. The robot design should focus more on functionality than anthropomorphic features.
   - Applicable to: Employee and Customer.
7. The robot should be designed in a way that enables it to be easily cleaned.
   - Applicable to: Employee and Customer.
8. The robot implementation should enable finished food to be delivered within a similar time frame as an all-human system.
   - Applicable to: Customer.
9. The robot should provide instructions during an interaction.
   - Applicable to: Customer.

Function

10. The robot should inform employees in case of incidents or malfunctions in order to resolve them quickly.
    - Applicable to: Customer.
11. The robot should have a clear way of displaying the reason for failure.
    - Applicable to: Employee.
12. An emergency stop button should be easily identifiable and reachable.
    - Applicable to: Employee and Customer.
13. If the robot collects data, it should be transparent about what data it collects and how it may be used.
    - Applicable to: Employee and Customer.
14. The robot should have different behaviours depending on the urgency of the task.
    - Applicable to: Employee.
15. The robot should be able to operate in busy situations.
    - Applicable to: Employee.
16. The robot should be able to operate after some furniture displacement.
    - Applicable to: Employee.
17. The robot should have an intuitive way of indicating movement.
    - Applicable to: Employee and Customer.

18. The robot should take avoiding action/actions to not cause a collision.
    - Applicable to: Employee and Customer.
19. The robot should be able to avoid getting in a position where it gets stuck.
    - Applicable to: Employee and Customer.
20. Food and drinks should be in a reachable height for sitting and standing.
    - Applicable to: Customer.
21. The robot should be able to transport food and drinks to customers without spilling.
    - Applicable to: Employee.
22. Features and functions of the robot should be customizable in a way that enables optimized use in different restaurant settings.
    - Applicable to: Employee.
23. The shelf design should be optimized to accommodate the anticipated quantity of plates as well as standard plate sizes commonly used in the restaurant segment.
    - Applicable to: Employee and Customer.
24. The robot should be constructed to handle heavy loads that match the number of desired plates.
    - Applicable to: Employee and Customer.
25. The robot should be able to operate within Swedish wheelchair accessibility dimensions.
    - Applicable to: Employee and Customer.
26. The customer should be able to call for human assistance through the system.
    - Applicable to: Employee and Customer.
27. The robot should be designed to assist in repetitive, heavy and time-consuming tasks.
    - Applicable to: Customer.
28. The robot should only be able to deliver food to one company (table) at a time.
    - Applicable to: Employee.
29. The restaurant should be able to operate, without the robot.
    - Applicable to: Employee.
30. Tasks or sequences of tasks should have to be initiated by an employee.
    - Applicable to: Employee.
31. The robot should be able to complete its initiated tasks autonomously with minimal human supervision.
    - Applicable to: Employee.
32. The robot should be flexible in what type of tasks it can perform.
    - Applicable to: Employee.
33. The robot should provide additional benefits to existing solutions.
    - Applicable to: Employee.
34. The anthropomorphic features should not be exaggerated.
    - Applicable to: Employee and Customer.

Interaction

35. The robot should only present collected data when relevant and necessary.
    - Applicable to: Employee and Customer.
36. The robot should adhere to norms of how similar technologies work in Sweden.
    - Applicable to: Employee and Customer.
37. The robot should have a non-disturbing level of communication.
    - Applicable to: Employee and Customer.
38. There indication of movement should be accessible.
    - Applicable to: Employee and Customer.
39. It should be clear what the next action of the robot will be.
    - Applicable to: Employee and Customer.
40. The robot interaction should have an appropriate level of perceived professionalism.
    - Applicable to: Customer.
41. Robot service interactions should be performed within a similar timeframe as human service interactions.
    - Applicable to: Customer
42. The robot should give the user a clear indication that it or the user has completed a task successfully.
    - Applicable to: Customer.
43. The robot UI should be e designed based on an established usability framework.
    - Applicable to: Customer.
44. The robot should make use of technologies that are perceived as reliable and mature.
    - Applicable to: Employee and Customer.

Desired result of Implementation

45. The robot should be designed to assist in repetitive and time-consuming tasks.
    - Applicable to: Employee.
46. The system should be optimized in full, to avoid suboptimization.
    - Applicable to: Employee.
47. The robot should provide relevant statics of how it is used.
    - Applicable to: Employee
48. The expected level of service should not be negatively affected by the use of a robot.
    - Applicable to: Employee and Customer.
49. The robot should fulfil its tasks to a satisfactory level which improves the work quality.
    - Applicable to: Employee and Customer.
50. The robot should facilitate better service opportunities for the employees.
    - Applicable to: Employee and Customer.
51. The robot should be pairable with additional technological systems.
    - Applicable to: Employee and Customer.
52. The robot should have features that could be changed between different restaurants to create a unique experience.
    - Applicable to: Employee.

Appendix B – Interview Questions

Interview Guide – Questions to Customer

Förväntningar för ett restaurangbesök

- Hur ofta äter du ute på restaurang?
- Vilka typer av restauranger föredrar du att besöka, och varför?
- Vilka kriterier är viktiga för ett uppskattat besök, enligt dig? Varför?
    - Hur skiljer sig dessa mellan olika restauranger?
- Vilka förväntningar har du på servicen när du går på restaurang?
    - Hur skiljer sig dessa mellan olika restauranger?

Attityder kring teknologi

- Hur ser du på att interagera med teknik under ett restaurangbesök? T.ex. beställa mat via din telefon istället för av en människa?
    - Varför?
    - Ser de olika ut för olika typer av restauranger?
- Hur ser din personliga inställning ut till teknologi? Är den positiv eller negativ, eller helt enkelt neutral?
    - Varför skulle du säga att du är positiv/negativ?

Attityder kring robotar – (Fokus på "hedonic motivation")

- Har du någon gång besökt en restaurang som på något sätt använt sig av en robot under serveringen?
    - Om ja, Var det ett aktivt val eller var det av en slump?
        - Om du försöker minnas tillbaka, hur var det?
    - Om nej, är detta ett aktivt val? Eller finns det någon annan anledning?
        - Varför i sådana fall?
        - Spekulera kring hur du tror att du hade upplevt det.
    - I vilket sammanhang hade det varit mest troligt att du besökte en restaurang med en serverings robot.
        - Hur ser din närmsta umgängeskrets på ny teknologi, särskilt då servingsrobotar?
            - Din familj?
            - Dina vänner?
- Vad har du för generella bild och åsikt angående serveringsrobotar inom restaurang?
    - Ser de olika ut för olika typer av restauranger?
        - Är den samma för en mer lyxig restaurant än ett snabbmatshak?
- Vad tror du att en robot på restaurang kan göra idag?
    - Vad hade du velat att den skulle göra?
    - Vad hade du absolut inte velat att den skulle göra?
- Hade du tyckt det varit roligt att bli serverad av en robot?
    - Tror du att det hade sett annorlunda ut beroende på vilken grupp du är i?
- Vad hade fått dig att fortsatt återvända till restauranger med serveringsrobotar?

Robotar - Effort Expectancy

- Tror du att det hade varit enkelt att interagera med en servicerobotar?
- Hade du upplevt det som jobbigt eller ett problem att lyfta av tallriken själv, istället för få den serverad?
  - Varför/varför inte?
  - Om ja, hade något annat kunnat väga upp för det isådanfall (t.ex om det går snabbare)?

Förväntningar på robotar och antropomorfism

- Genom att titta på dessa bilder vad förväntar du dig att dessa robotar kan utföra för uppgifter? (The images are not included due to copyright reasons).
  - Hur förväntar du dig att dessa olika robotar skulle kommunicera med dig som kund
  - Vilken robot upplever du mest intelligent?
  - Vilken robots utseende föredrar du? Varför? I vilket sammanhang?
  - Vilken robots utseende tycker du ej är lämplig? Varför?
- I vilka typer av restauranger anser du att dessa robotar passar? Varför, varför inte?

Tillit till robotar

- Hade du varit bekväm i en situation med en robot?
  - Varför, varför inte?
  - Hade du t.ex. blivit rädd för att bli påkörd?
  - Förmedla hur den ska röra sig
  - Hur är din tillit till teknologi rent generellt?
- Om de hade blivit fel, hur hade du känt

Övrigt

- Är det något som vi glömt att nämna som du hade velat lyfta angående restaurangrobotar?
- Männsklig kontakt – Något element du hade saknat eller inte saknat?

Interview Guide – Questions to Employees with Experience of Robots

Frågor om restaurangen de jobbar på

- Hur profilerar ni er som restaurang?
    - Vilka är era kunder?
        - Vilket är erat kundsegment?
- Vad är eran personalomsättning på ett ungefär? Har ni ett högt eller lågt utbyte av personal?
    - Om hög: Upplever ni det som ett problem? Vad gör ni för att undvika det?
- Hur länge har ni haft en robot?

Vilka typ av uppgifter som de utför på jobbet

- Vilka uppgifter har du på jobbet? Är det någon uppgift som är särskilt repetitiv? Någon du hade föredragits hade tagit över av någon annan?
- Vilka uppgifter innebär någon form av kunderinteraktion?
- Vilka uppgifter har du på jobbet som <u>inte</u> innebär kunderinteraktion?
- Är det någon uppgift som tar extra mycket tid?
- Upplever du att någon uppgift är onödig och hade kunnat hanterats på annat sätt?

Attityder

- Vad är din personliga inställning till teknologi? Är den åt det positivare hållet, eller tvärt om?
    - Varför skulle du säga att du är positiv/negativ?
- Vad skulle du säga är din inställning till teknologi på jobbet? Stämmer den överens med din personliga?
    - Använder du någon särskild teknologi idag på jobbet?
    - Vad skulle få dig att använda teknologiska lösningar till en högre grad på jobbet?
- Vad är din inställning till Artificiellt Intelligens?
    - Upplever ni att den roboten har som ”intelligent”? Varför, varför inte? På vilket sätt?
- Vad är din allmänna uppfattning kring servicerobotar inom restaurang?
    - Hade du själv uppskattat att blivit serverad av en robot?
- Hur tror du att roboten har/hade påverkat bilden av er som restaurang?
    - Vad är din uppfattning kring hur era kunder ser på service roboten?
    - Minns du någon/några specifika kommentarer som sagts om roboten?

Frågor kopplade till teknologi acceptans modellerna (ISTAM)

- Hur var första tiden med roboten? (Försök minnas så bra du kan).
    - Något som stack ut? Var det svårt att lära sig?
    - Vilka uppfattningar hade du innan du använt roboten?
    - Kände du att du kunde vara med och påverka i beslutet att skaffa en servicerobot?
- Har ni behövt göra några förändringar i layouten på restaurangen? Dvs möblera om eller lägga till ramper eller liknande?
- Hur är dina kollegors syn på robotimplementeringen?
    - Är det någon särskild på jobbet som har tagit mer ansvar för roboten?
    - Varför denna person? Särskild utbildning, mer teknikintresserad?
- Har du sett några förändringar i sättet ni arbetat sen ni implementera roboten? På vilket sätt?

    - Har roboten underlättat ditt personliga arbete? På vilket sätt?
    - Ser du eller ni att någon arbetsuppgift försvunnit helt?
        - Ser du på detta som positivt eller negativt?
    - Ser du eller ni att någon arbetsuppgift tillkommit?
        - Ser du på detta som positivt eller negativt?
    - Hur ser arbetsfördelningen ut? Vem rengör, plockar av i disken etc.?
    - Har du någon gång känt en rädsla över att din roll ska försvinna, och därmed förlora jobbet?

Användning (faktiska)

- Vad anser du om er robots förmåga att utföra sina uppgifter?
- Upplever du att roboten är lätt att använda?
- Upplever du att ni har kontroll över roboten?
    - Tycker ni det är lätt att få roboten att göra som ni vill?
- Har de funnits saker med roboten som du velat ändra?
    - Är det något ni saknar som roboten i er åsikt bör kunna ha?
    - Har ni möjlighet att ändra några egenskaper hos roboten?
        - Hur går detta till? Inställningar, eller fysiskt?
        - Är detta något du eller ni saknar?
- Uppskattar du att arbeta med roboten?
- Vad tycker du om eran robots utseende?
    - Upplever den att den matchar resten av ert restaurangs koncept?
- Hur upplever du att roboten kommunicerar med sin omgivning?
    - På vilket sätt?
    - Upplever du den som intelligent?
- Har du tillit till robotens förmåga att arbeta bland människor?
    - Har de skett någon incident?
- Vet du varför det hände?
- Händer det iblanda att roboten gör fel, på vilket sätt?
    - Hur påverkar det din tillit?
- Är det något annat du vill lyfta angående att jobba med en robot?

Interview Guide – Questions to Employees without Experience of Robots

Frågor om restaurangen de jobbar på

- Hur profilerar ni er som restaurang?
  - Vilka är era kunder?
    - Vilket är erat kundsegment?
- Vad är eran personalomsättning på ett ungefär? Har ni ett högt eller lågt utbyte av personal?
  - Om hög: Upplever ni det som ett problem? Vad gör ni för att undvika det?

Vilka typ av uppgifter som de utför på jobbet

- Vilka uppgifter har du på jobbet? Är det någon uppgift som är särskilt repetitiv? Någon du hade föredragits hade tagit över av någon annan?
- Vilka uppgifter innebär någon form av kunderinteraktion?
- Vilka uppgifter har du på jobbet som <u>inte</u> innebär kunderinteraktion?
- Är det någon uppgift som tar extra mycket tid?
  - Upplever du att någon uppgift är onödig och hade kunnat hanterats på annat sätt?

Attityder

- Vad är din personliga inställning till teknologi? Är den åt det positivare hållet, eller tvärt om?
  - Varför skulle du säga att du är positiv/negativ?
- Vad skulle du säga är din inställning till teknologi på jobbet? Stämmer den överens med din personliga?
  - Använder du någon särskild teknologi idag på jobbet?
  - Vad skulle få dig att använda teknologiska lösningar till en högre grad på jobbet?
- Vad är din inställning till robotar generellt? Att de t.ex. implementeras i mer vardagliga situationer?
  - Upplever du teknologi idag som intelligent?
- Vad är din allmänna uppfattning kring servicerobotar inom restaurang?
  - Hade du själv uppskattat att blivit serverad av en robot?
- Hur tror du att roboten hade påverkat bilden av er som restaurang?
  - Hur tror du era kunder hade mottagit en robot?

Frågor kopplade till teknologi acceptans modellerna (ISTAM)

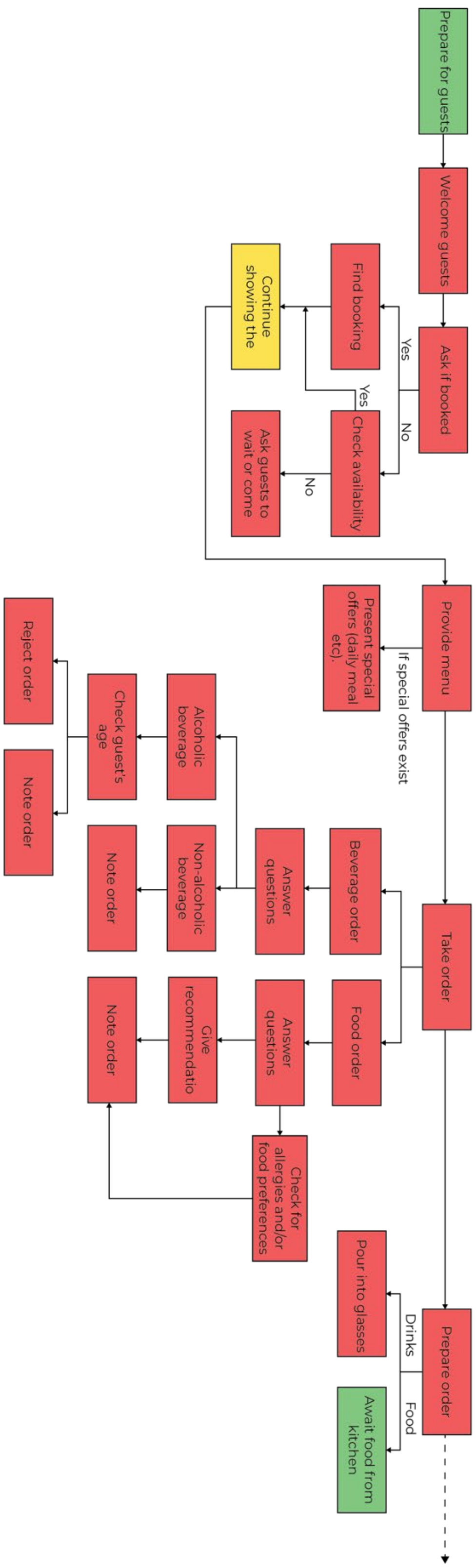
- Hade du velat ha en robot på er restaurang?
  - Varför, varför inte?
  - Hade du fått vara med i beslutet att införa en sådan tror du?
- Har ni behövt göra några förändringar i layouten på restaurangen? Dvs möblera om eller lägga till ramper eller liknande?
- Vad tror du att dina kollegor hade haft för inställning till en eventuell robot implementering?
  - Är det någon särskild på jobbet som du tror hade tagit mer ansvar för roboten?
- Hade erat jobb ändrats på något sätt? Hur tror du då? Fritt fram att spekulera med den kunskapen ni har?
  - Hade roboten kunnat underlättat ditt personliga arbete? På vilket sätt?
  - Tror du att någon av era arbetsuppgifter hade försvunnit helt?
    - Ser du på detta som positivt eller negativt?

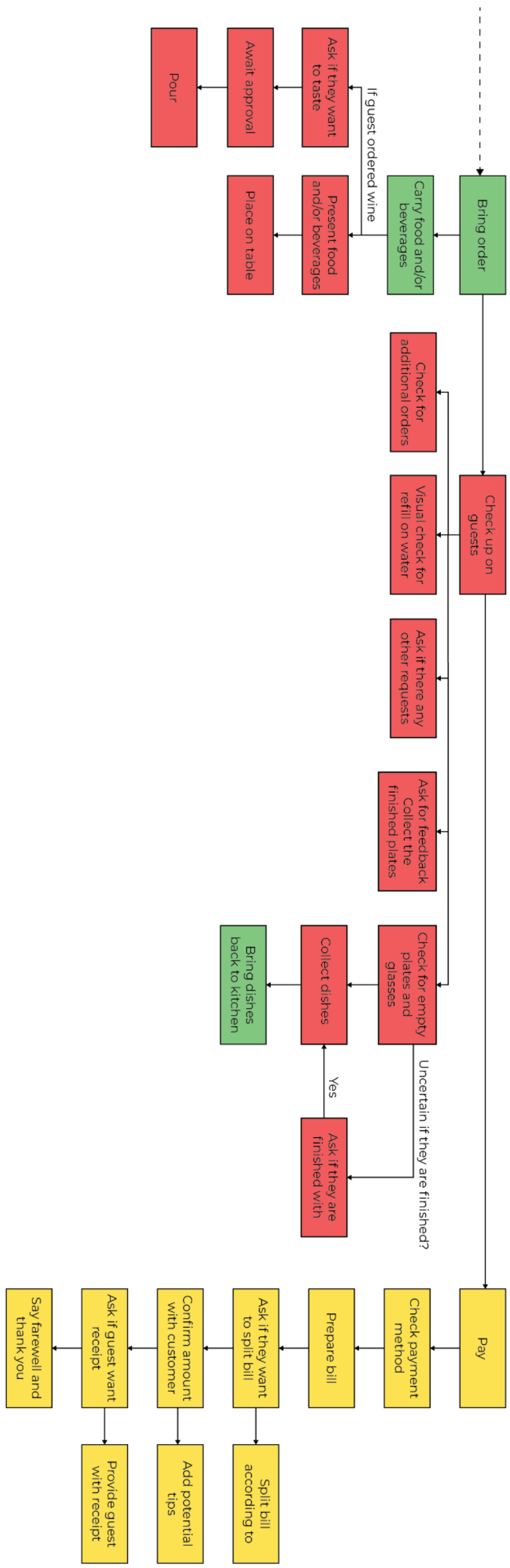
    - Ser du eller ni att någon arbetsuppgift tillkommit?
        - Ser du på detta som positivt eller negativt?
    - Känner du en rädsla över att din roll hade försvunnit?

Användning (förväntningar)

- Vilka uppgifter förväntar du dig att en robot i restaurang ska kunna utföra?
- Hur svårt tror du det är att implementera en robot? Tror du den är svåra att använda?
- Tror du att ni som restaurang är redo att använda en restaurang robot?
    - Finns teknisk kompetenes?
    - Finns det en orginasation som kan stötta er som är tänkta att använda den?
- Tror du att du hade uppskattat att arbeta med en robot?
- Hur hade du velat att roboten kommunicerar med sin omgivning? Dvs lampor, ljud osv?
    - Varför?
- Tror du att robotens utseende spelar roll för ur den kommer mottas?
    - På vilket sätt?
    - Vad är optimalt enligt dig?
    - Vad får inte lika bra enligt dig?
- Hade du haft tillit till robotars förmåga att arbeta bland människor? Varför/varför inte?
- Är det något annat du vill lyfta angående robotar inom restaurang?

Appendix C – HTA




Bring order
Carry food and/or beverages
If guest ordered wine
Ask if they want to taste
Await approval
Pour
Present food and/or beverages
Place on table
Check up on guests
Check for additional orders
Visual check for refill on water
Ask if there any other requests
Ask for feedback Collect the finished plates
Check for empty plates and glasses
Collect dishes
Bring dishes back to kitchen
Uncertain if they are finished?
Ask if they are finished with
Yes
Pay
Check payment method
Prepare bill
Ask if they want to split bill
Split bill according to
Confirm amount with customer
Add potential tips
Ask if guest want receipt
Provide guest with receipt
Say farewell and thank you

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