Autonomous delivery robots

Research into the acceptance of and market for the technology

Module 5: Research and design
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Future Mobility Network

Preface

This report is written by four students of the Leiden-Delft-Erasmus (LDE) minor called 'Smart and Shared Cities'. This study is part of the concluding module 'Research participation and projects'. Commissioned by the Future Mobility Network, research has been conducted into the acceptance of and market for autonomous delivery robots. The Future Mobility Network plays a crucial role in a pilot with the autonomous delivery robot ROSIE. Our student team contributes to the pilot by doing research. We complement each other's work through our different academic backgrounds because we approach problems and research in diverse ways. This proved to be useful for tackling the different sides of the Future Mobility Network's problem.

It is assumed that the reader has basic knowledge of autonomous robots. However, the introduction also pays attention to the technology. Readers unfamiliar with the statistical analysis methods that are used for this research can find an explanation in the appendices of the respective models. Readers with an interest in the design of the study can find the explanation of this in Chapter 3.

We would like to thank our professor, dr. J.R. Ortt and Merlina Slotboom for guiding this module and answering questions. We also thank Tim Klein for providing feedback, answering questions about the pilot and ROSIE, and guiding us throughout the project.

We believe that research about automated delivery robots is important as we expect them to soon dominate our cityscapes and, therefore, affect economic, societal, and environmental structures. Furthermore, we found compiling and writing this report a fun and challenging process. Hopefully, our findings can help define and execute future steps for autonomous delivery robots in the Netherlands.

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Executive summary

Automated delivery robots (ADRs) are branded as more sustainable and cost-efficient alternatives to conventional types of delivery. They constitute a possible future for last-mile delivery. Most European ADR programs are still in the testing phase, as the technological, regulatory, and societal implications of such business models still need to be researched and defined.

In the Netherlands, ADRs are not yet allowed to operate in public spaces. The Future Mobility Network, a Dutch urban technology consultancy company, wants to bring ADRs to the roads of the Netherlands. However, before this can happen, they must ensure that ADRs are accepted by the citizens of the Netherlands and there is a market for this technology. This research focuses on these aspects and tries to address these issues in depth. There are two questions central to this research; To what extent are autonomous delivery robots (ADRs) accepted in the Netherlands by the citizens? How can autonomous delivery robots (ADRs) be applied in the Netherlands?

The research has been conducted with the help of several quantitative statistical methods and is complemented by qualitative content analysis. Factor analysis and conjunct experiments formed the basis of the quantitative statistical analysis; the data was gathered from a survey with 213 respondents. For the qualitative analysis, interviews, open-ended survey questions, and comparative literature research were conducted.

Several stakeholders need to be considered once ADRs get deployed to public spaces in the Netherlands. This includes local governmental RDW (Dutch vehicle authority department), businesses that offer delivery services like supermarkets, technology companies, and citizens.

Three main insights are found. Firstly, people are willing to accept ADRs but are hesitant to use them. The perceived usefulness was mainly limited because of the short delivery distance. Secondly, people seem to accept ADRs more after they have seen such technology in action. So, the Future Mobility Network could promote ADRs by showing pictures and videos of ADRs in action. Additionally, they should do live demos of ADRs delivering goods. Lastly, the respondents of the survey indicated that there is a mismatch between the price charged for the service and the distance of the delivery.

It is recommended that the Future Mobility Network looks at ways to improve acceptance and the demand for the technology. Demos with ADRs, specifically among the elderly, could be used for this. Additionally, future research should investigate other factors such as weather conditions, time of the day, technology literacy, postcodes, and the usage of delivery services, in relation to their influence on the acceptance and use of ADRs. The most promising use cases for the Future Mobility Network are industrial sites and delivery services for immobile people.

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1. Introduction

As cities rapidly grow, infrastructure becomes more complex, and last-mile delivery demands surge, subsequently pollution, traffic congestion, and other hazards in cities may increase. Last-mile delivery, meaning the delivery of goods from the warehouse or store directly to the customer, becomes a challenge in bigger cities due to these changes (Mordor Intelligence, n.d.). Autonomous delivery robots (ADRs) are branded as solutions to last-mile delivery challenges as they are more cost- and energy-efficient, than conventional delivery systems. In part, this is because conventional delivery vehicles emit around 100 times as much CO2 per km per order (Pani et al., 2020). Thus, the application, accessibility, and acceptance of ADRs are growing worldwide and ADRs are changing the last-mile delivery sector (Mordor Intelligence, n.d.; Pani et al., 2020).

While ADRs are already established tools in North America and Asia-Pacific, Europe is lacking behind and is only starting to establish such technologies (Mordor Intelligence, n.d.). Most European ADR programs are still in the testing phase, as the technological, regulatory, and societal implications of such business models still need to be researched and defined. The lack of research and regulations has also posed a challenge for companies who want to employ ADRs in the Netherlands. The Future Mobility Network is a Dutch urban technology consultancy company that focuses on transportation, logistics, and urban area development, which wants to deploy ADRs in public space (i.e., public roads, public parks, etc.) in the Netherlands (The Future Mobility Network, 2019). The Future Mobility Network is strongly involved in research about ADRs and is currently part of a pilot with an ADR named ROSIE on the Erasmus Woudestein campus in Rotterdam. Knowledge about the application of ADRs in the Netherlands is necessary before ADRs can be operational in the city and improve last-mile deliveries.

The Future Mobility Network aims to increase understanding of the use case and acceptance of ADRs in the Netherlands. Commissioned by the Future Mobility Network this research focuses on the acceptance of ADR technologies by citizens. The aim is to determine how the technology is received by citizens and whether there is a market for the technology in the Netherlands. Secondly, the research ties into a wider exploration of how different populations react to new, smart, technologies such as ADRs. With the gained knowledge broader conclusions could be drawn about the behaviour and incentives towards e.g., autonomous robots.

This research presupposes that the acceptance of ADRs is crucial as it on one hand facilitates a more seamless operation on the street (bystanders will be more cooperative during operation) and on the other hand increases the demand for deliveries by ADRs. More specifically, this research aims to explore the acceptance of ADRs by citizens in the Netherlands. The following research questions are central to the study:

1. To what extent are autonomous delivery robots (ADRs) accepted in the Netherlands by the citizens?
2. How can autonomous delivery robots (ADRs) be applied in the Netherlands?

To arrive at conclusions, a combination of different methodologies will be used. Firstly, statistical analyses such as factors analysis, logistic regression, and chi-square tests will be performed. The statistical analyses will be carried out on survey data. The survey will be distributed on various online platforms among people living in the Netherlands. Secondly, qualitative data such as interviews, newspaper articles, and comments from the survey, will be analysed. Finally, a literature review will put the research and data into perspective.

The report is structured as follows. In Chapter 2, ‘problem formulation’, the different stakeholders, the context of the research, and the knowledge gap that this study aims to fill are introduced. Chapter 3, ‘research design’, will describe the diverse quantitative and qualitative research methods that lead to the research results. The results of the research will be laid out in Chapter 4, ‘results. Finally, in Chapter 5, ‘conclusion’, the main findings, and insights from the research will be summarised. In addition, a recommendation is given to the Future Mobility Network and further research is suggested.

2. Problem analysis

With the rise of new autonomous technologies, The Future Mobility Network wants to bring ADRs to the Netherlands. However, before being allowed to deploy these robots in public space, it is necessary to do research and learn more about how well the ADRs are accepted by citizens. This can help to predict how well this technology will be adapted in the Netherlands. Moreover, it can aid the Future Mobility Network to have a preliminary understanding of the markets of ADRs. This is because research on acceptance will provide some indication of the extent to which the technology will be embraced by the potential users.

When ADRs will be deployed in public spaces in the Netherlands, the following stakeholders will be involved. Firstly, the government is involved because they make the rules and regulations on how ADRs will operate in public space. The Dutch vehicle authority department, RDW, will be heavily involved as they have jurisdiction over the types of vehicles that can operate in Dutch public spaces (RDW, 2022). If ADRs get deployed to public spaces, they will primarily be involved with registration, supervision, and licensing issues. Secondly, businesses that offer delivery services (e.g., supermarkets and restaurants) are involved as it will restructure and potentially revolutionise their delivery operation. Furthermore, technology businesses are a stakeholder as there will be an increase in demand for their technical services to develop ADRs. The role of citizens in public space will also be crucial as the autonomous delivery robots will interact with them. Examples of such interactions include citizens using the delivery services and collecting items from the robot, and citizens sharing public space with the robots.

Limited research has been done about the acceptance of ADRs in the public space in the Netherlands. A key reason for the knowledge gap in the Netherlands is that this technology has not yet been implemented at all in the Netherlands. In contrast, there has been a significant amount of research done on the acceptance of automated delivery robots in other parts of the world, mainly, the United States and the Asia-Pacific region. For example, in 2020, the department of civil engineering from the University of Memphis published a paper on ‘Evaluating public acceptance of autonomous delivery robots during COVID-19 pandemic (Pani et al., 2020). This study initiates to fill the existing knowledge gap about the acceptance of ADRs in the Netherlands. Moreover, the study provides useful information for the Future Mobility Network, as they want to implement a business with ADRs in the Netherlands, and knowledge about the potential customers is crucial for a successful implementation.

To get insights into the acceptance of the ADR technology by Dutch citizens, the research will firstly focus on the aspects of people’s perceptions towards the technology, socio-demographic factors, and the effects of familiarity of the technology's acceptance. As a result, the following research questions will be answered:

1. To what extent are autonomous delivery robots (ADRs) accepted in the Netherlands by the citizens?
    a. How do people perceive ADRs?
    b. What is the average acceptance of ADRs in the Netherlands by citizens?
    c. How do socio-demographic characteristics (gender, age, level of education, employment status, professional area, income, and residence) influence the extent to which ADRs are accepted?
    d. How does familiarity with ADR technology influence to what extent ADRs are accepted?

The second research question and sub-questions are aimed at understanding how ADRs can be practically applied in the Netherlands. Therefore, these questions analyse the issue of price sensitivity of potential customers. This will be examined using two variables: the price charged for the delivery service, and the distance of the delivery. Moreover, these questions look at use cases of ADRs in the Netherlands. This focus results in the following research questions:

2. How can autonomous delivery robots (ADRs) be applied in the Netherlands?
    a. How do the price charged for delivery and the range of delivery distance influence the decision to use the delivery robot?
    b. What are the most promising areas of application for ADRs?

The focus of this study is limited to (semi-)public spaces in the Netherlands. Thus, the focus is on the acceptance of autonomous robots on streets, in parks, and on public roads. Public spaces outside of the Netherlands are excluded from this study since the Future Mobility Network is interested in the use of robots exclusively in the Netherlands.

The result of this study will consist of insights into the acceptance of ADRs by citizens. Based on this, advice will be given on what factors and groups of citizens (e.g., elderly, students, people with a low income) could be considered when looking at the application plan for the robots. Second, the research will provide advice on possible use cases for ADRs to the Future Mobility Network. This is valuable information for The Future Mobility Network because it will help them with the deployment of the robot.

3. Research design

The aim of this chapter is to lay out the methods used to address the research questions. To answer the research questions a combination of methods is used. A survey is distributed, and the results are statistically analysed. Factor analysis is used to answer the extent of the average acceptance of ADRs by citizens in the Netherlands. Moreover, linear regression analysis is used to answer how socio-demographic characteristics and familiarity with ADR technology influence to what extent ADRs are accepted. Logistic regression analysis is used to answer how the price charged for delivery and the range of delivery distance influence the decision to use the delivery robot. Additionally, interviews, literature research, and qualitative analysis of the survey results help to get insight into how people perceive ADRs and what promising areas are for the application of ADRs.

Chapter 3.1. further discusses the use of the survey and the different methods of statistical analysis of the survey results. Chapter 3.2. provides insight into the application of interviews, literature research, and qualitative analysis within this study.

3.1. Survey and statistical analysis

The survey is the main research method and is used to obtain insights into the acceptance of ADRs among people living in the Netherlands and the market for this technology (see Appendix B). More precisely, factor analysis and a conjunct experiment form the basis of the statistical analysis that provides these insights. The conceptual models underlying the statistical analysis are included in Appendix A.

Factors analysis is a statistical analysis method that can be used to measure psychologically latent variables that cannot be observed directly. For this research, ten statements regarding ADRs are used to measure the latent variable 'acceptance'. This is described in more detail in Appendix B.3.

A conjunct experiment is a type of choice experiment designed to measure how much value people attach to attributes of a system feature. This is a trade-off between price and service. Therefore, the respondent was presented with different 'situations', with varying prices and delivery distances. Through this, it could be analysed how different prices and distances would affect the willingness to use ADRs. In Appendix B.4, the operation of this method is further elaborated.

The survey entails the conjunct experiment, statements about acceptance, and other questions and is presented in Appendix C. The data obtained by the survey is analysed with different statistical data analysis methods. As mentioned, factor analysis is used to retrieve insights into the acceptance of ADRs. Additionally, chi-square analysis and linear regression are used to evaluate the sample and its effects on the results. To answer how the price charged and distance of delivery influence the decision to use the delivery robot, the method of binary logistic regression is used.

3.2. Interview, literature research, and qualitative analysis

Interviews conducted during on-site work with ROSIE, are used as a secondary method in this research, to better understand the acceptance of ADRs. Despite that only a few interviews have been conducted, they revealed new insights and contextualised the statistically measured acceptance of the population. Additionally, opinions about ADRs were collected with an open-ended question in the survey.

These qualitative analysis methods not only aid in getting a more thorough understanding of ADRs and how people living in the Netherlands perceive them but also allow for the exploration of new use cases for ADRs like ROSIE. In addition, the qualitative analysis makes it possible to compare the findings to existing literature. This is a field, in which not a significant amount of research has been conducted in Europe.

4. Results

In this chapter, the results of the various analyses are discussed. Chapter 4.1. discusses the results of the statistical analysis. This includes the factor, chi-square, and regression analysis. Thenceforth, Chapter 4.2. contains the results of the qualitative analysis.

4.1. Results statistical analysis

The extent the sample of the survey represents the citizens of the Netherlands and how this might influence the results. The sample of the survey consists of 213 responses. The sample is not representative of the population, following the chi-square analysis (see Appendix E.2). The sample distribution of all socio-demographic variables, except gender and residence, is not in line with the population distribution. However, this does not affect the results because the level of acceptance does not vary between the different values of the socio-demographics. To demonstrate, age does not influence acceptance significantly. This was derived by the linear regression analysis of the effect of the parameters of the socio-demographic characteristics on the composite scales of the factors (see Appendix E.3). One parameter does show a statistically significant deviation. This is the parameter 'countryside', one of the categories of the socio-demographic factor 'residence'. Nevertheless, this does not necessarily affect the results of the study since there is no information on the extent to which the sample distribution of 'residence' differs from the population's distribution.

Factor analysis is used to measure the acceptance of ADRs. The factor analysis is based on ten statements regarding ADRs. The factor analysis results in two factors that can explain the variance in the scores of all statements, except the statement on privacy invasions by ADRs (statement 3) and on the malfunctioning of ADRs (statement 7) (see Appendix E.1). The first factor can be interpreted as 'concerns about ADRs' as most of the variance of the scores on statements 4, 1, 10, and 2 can be explained by this factor. A high score of this factor indicates a lot of concerns about ADRs. The second factor can be interpreted as 'usability of ADRs' since the scores of statements 5, 6, 8, and 9 are explained by this factor. A high score of this factor indicates a low usability of ADRs because if someone scores high on for example statement 6 this leads to a high score on the factor. This is the case if someone strongly agrees that it is difficult to collect groceries when they are delivered by an ADR, and thus does not find the technology useful.

Two compound scales are created of the average sum scores of the scores of the statements that can be explained by each factor. These compound scales are a new variable with the name of the two factors. Cronbach's alphas of respectively 0,617 and 0,484 for factor 1 'concerns about ADRs' and factor 2 'usability of ADRs' indicates medium and high reliability of the new scales (see Appendix E.1). This suffices to use the factors in the regression models because it is an exploratory study. The average of concerns about ADRs is 2,29 (see Appendix E.3). This can be interpreted in the original scale of a score between 1 and 5, with 5 being a lot of concerns and 1 being no concerns. So, even though there are people with concerns (standard deviation is 0,627), on average the concerns are low. This first factor can be used as an indicator for acceptance, which means that the average is that people are in favour of ADRs. The average usability of ADRs is 2,60 and has a standard deviation of 0,601. This shows that people do find ADRs useful.

The linear regression analysis shows that none of the socio-demographic characteristics influences the 'concerns about ADRs'. And only the 'residence' characteristic influences the 'usability of ADRs'. People who live in the city find ADRs more useful than people who live in the countryside. This is shown in Appendix E.3. Although other effects cannot be generalised to the population, interesting effects were found in the sample. Firstly, on average, retired, disabled and other people find ADRs less useful than workers or students. This is an interesting finding because it was expected that using ADRs could potentially aid specifically this demographic group with e.g., everyday groceries. Further research could reveal the reasons for such differences between the occupation groups. Secondly, people with a job in an ADR-related field (i.e., IT, engineering, production and construction, and transport and logistics) are less concerned about ADRs, but at the same time find them less useful. A second linear regression model shows that the concerns are negatively affected by people's familiarity with the technology. This is an important starting point when it comes to increasing acceptance.

The binary logistic regression analysis has three important results (see Appendix E.4). Firstly, it indicates that a lower price comes with higher chances of people choosing to order from ADRs instead of picking up the groceries themselves. Secondly, the chance of choosing to order from ADRs also increases when the distance of the delivery increases. Distance has a bigger influence on the choice to order than the price. Lastly, the chance of choosing to order from ADRs is higher when the appointed usability is higher.

4.2. Results qualitative analysis

There are 31 comments from the survey that are analysed. In combination with the interviews and analysis of news articles, the results highlight different use cases for the robot and additional potential risks. Based on the elaborate analysis in Appendix D, there have been numerous findings concerning the use cases of the robot suggested by the respondents.

Firstly, use cases where the robot could be utilised are in spaces that are unwalkable for employees. These can be industrial sites, as ADRs could reduce the expenditure of installing costly infrastructure for robots that currently operate on fixed, pe-installed tracks. The Future Mobility Network could expand by deploying ADRs in hospitals, to deliver supplies. There are several challenges when it comes to using ADRs inside hospitals, such as people in corridors, and wheelchairs. However, the variety of barriers is limited compared to public spaces where there is traffic. ADRs can potentially allow medical workers to focus on more essential tasks. Additionally, ADRs can reduce the delivery efforts in big offices for package or letter deliveries. Lastly, airports could be a potential use case since this operational design area is suitable for the technology.

Secondly, supporting less mobile citizens could be a use case for ADRs (Appendix D). The Future Mobility Network should focus on two different target groups. The first one is less mobile citizens. ADRs can be implemented to supply them with groceries, and other crucial items. At the current stage of the technology, this is possible for people residing in single-story buildings. As the technology advances, ADRs can communicate with the house IT system to open the door and call the elevator. This will enable the expansion of the delivery service to multi-story buildings. A big part of this target group is the elderly since they are often less mobile. However, the elderly are often less familiar with smartphones, and novel technologies and thus technology illiterate. Therefore, deploying autonomous delivery services among them is a challenge. Still, this is a potential use case and market opportunity, since the population is aging and ADRs offer this group a way to independently collect groceries. In conclusion, offering delivery services to immobile people should be a subject of future research.

5. Conclusion

The emerging technology of ADRs is being applied in more and more places. Before it is possible to use ADRs in the public space in the Netherlands, several matters need to be clarified. This study focuses specifically on the acceptance of ADRs among residents of the Netherlands and on the market for this technology. Using statistical and qualitative analyses based on a survey, interviews, and literature, several important findings are made regarding ADRs in the Netherlands.

The first group of findings is related to the research question 'To what extent are ADRs accepted in the Netherlands by the citizens?'. In general, ADRs are discussed positively by citizens and people who are interested in the operation. However, the current maximum delivery distance and use case are questioned. There may also be opportunities for ADRs in hospitals or large industrial areas. The extent to which people accept ADRs is not influenced by socio-demographic characteristics. However, ADRs are found more useful by people who live in the city than people who live in the countryside. Additionally, it can be concluded that people who have seen the ADR in action are less concerned about the robot and more accepting of the technology. The level of acceptance is high enough to conclude that ADRs can be used in the Netherlands because on average people do not have a lot of concerns.

The second set of conclusions answers the question 'How can ADRs be applied in the Netherlands?'. As expected, the demand for deliveries by ADRs decreases as their price increases. But even when delivery is free, demand is not high. There is certainly little demand if the delivery range (i.e., distance) is small. This poses the question of whether there are enough people who would use ADRs. This also proves that longer-range deliveries are a promising area of application, along with using ADRs to help less mobile people in the facility of essential goods and using ADRs on industrial sites.

5.1. Limitations and further research

In this section, the methodological errors of the research will be addressed. They will be evaluated according to their possible negative influence on the research data and how future researchers could learn from the mistakes. Moreover, suggestions for possible further research will be given

Firstly, the reach of the survey imposed limitations on having a representative overview of the opinion of the elderly in the Netherlands. Future research should consider ways to map the opinions of this demographic group by spreading the survey via additional channels (i.e., post, in person), or conducting focus groups. It is important to reach this group because they are potential customers. Besides that, focus groups could provide an opportunity to showcase how ADRs can be beneficial in their everyday life.

Secondly, in addition to the socio-demographic factors included in this research, it would be beneficial to look at more factors. Data on additional factors could further aid in understanding the relationship between socio-demographic factors and the acceptance of ADRs. The following factors are suggested to be researched: postcode (2-digit accuracy), technology literacy, usage of other novel technologies (e.g., e-scooters or mobile payment by respondent), and general usage of delivery services. Researching postcodes, for example, could lead to insights on where ADRs could be deployed in public space.

Thirdly, the conjunct experiment has some drawbacks as the experiment is not completely representative of the real-life decision-making process of a customer. For example, the experiment only includes the choice to order from an ADR and to pick up the groceries yourself. However, in real life, you could also let groceries be delivered by humans. This results in a low ecological validity. Another point of concern is that the conjunct experiment neglects other factors that influence a choice to order from an ADR or not. These factors could include weather conditions, time of the day, and the type of the grocery. To improve understanding of the market a new conjunct experiment could be done that includes more factors.

Lastly, the research employs a positivist approach as its main method is to reveal statistical relationships between variables. Further research should focus on a more interpretivist methodology. Moreover, qualitative research as this could reveal insights about why certain socio-demographic groups either accept or do not accept ADRs. Further, more extensive qualitative research would aid to identify confounding variables and thus help to mitigate erroneous conclusions.

5.2. Recommendation

Overall, people accept ADRs but do not want to use them. Especially since the distances of delivery are small, the technology is perceived as redundant. Therefore, the recommendation for the Future Mobility Network is twofold.

The question 'What is enough acceptance?' should be asked. If the goal is that people are not against the technology and that they will not antagonise it in any way, then this goal is mostly met. However, if the goal is to have such a high acceptance that everyone wants to use the ADRs frequently, then there is still some work to be done. One way to improve the acceptance is by showing people ADRs while they are in operation. For this, the robot should operate in more places or video material could be used as promotion. Doing so could not only improve acceptance but also boost demand for the delivery service of ADRs.

Additionally, the Future Mobility Network should look for options to increase the delivery range of the ADRs and deploy the ADRs in other use cases. Based on this research, industrial sites could provide a feasible opportunity for The Future Mobility Network to offer cost reductions with the ADR technology. To offer a social impact in a growing market the Future Mobility Network is advised to explore ways how it can establish delivery services for the elderly. It is essential for the Future Mobility Network to constantly monitor the delivery market, which is divided among humans, autonomous robots, and drones. Increasing the delivery range and looking at ways for ADRs to travel upstairs is an opportunity to differentiate themselves and acquire a significant portion of the growing market of delivery services.

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Appendices

Appendix A – Conceptualisation

This appendix contains the conceptual models underlying the statistical analysis. The analysis can be split into parts that have different aims. The first aim is to find out to what extent the technology of autonomous delivery robots (ADRs) is accepted among people living in the Netherlands. The basis (i.e., conceptual model) for this part is discussed in Appendix A.1 and Appendix A.2. To determine the market for groceries delivered by an ADR is the second aim. Appendix A.3 elaborates on this part.

A.1. Conceptual model 'acceptance'

This section contains the conceptual model for the factor analysis. Factor analysis is used to reduce a high number of variables into fewer dimensions, which are the factors. Figure 1 shows the conceptual model focused on the acceptance of ADRs. The extent to which a person accepts ADRs determines the extent to which he or she agrees with the statements. These statements relate to autonomous delivery robots (see Appendix B.3). This means for example the following: if someone accepts the technology, then this person does not agree with the statement 'I do not want to encounter an ADR in public space'. The scores on the statements are also partly determined by the error component. The error component is the unique variance of the relevant respondent and is that part of the variance that is specific to that statement. In addition, the measurement error is part of the error component.

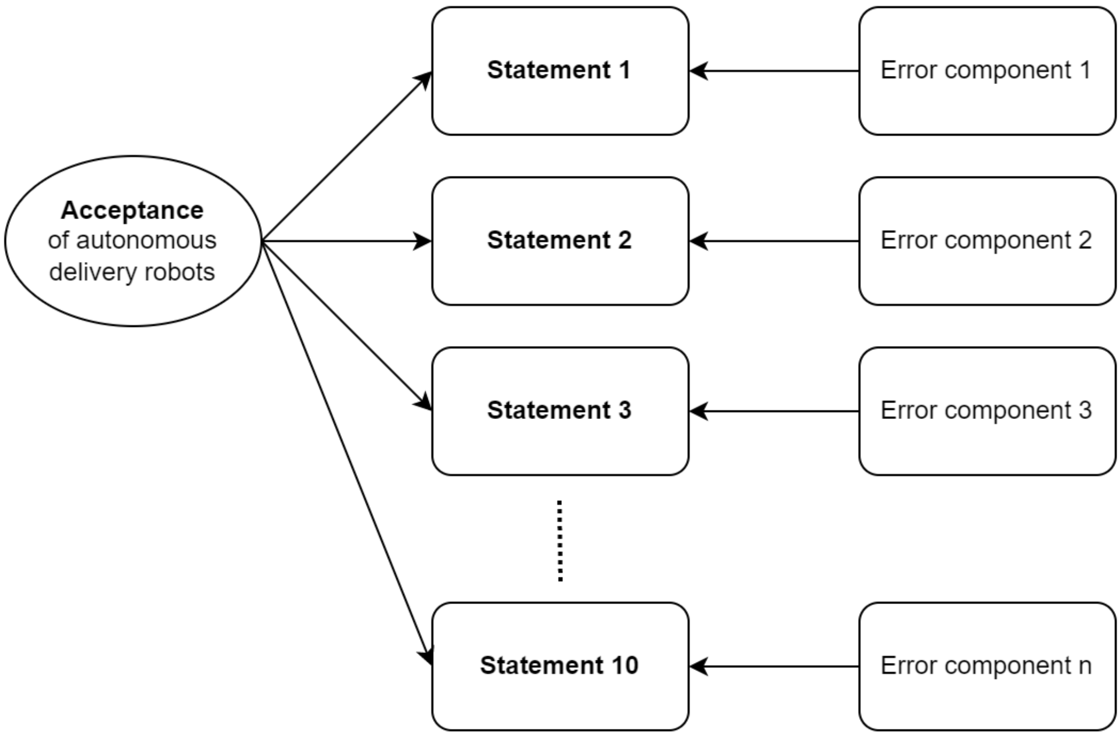

Figure 1: Conceptual model of acceptance

A.2. Conceptual model 'socio-demographic factors'

Gender, age, level of education, employment status, professional area, income, and type of residential neighbourhood are socio-demographic factors that can influence the variables of interest. It is therefore investigated what the influence of these factors is on acceptance. Figure 2 shows the conceptual model, which is the basis for the linear regression model that estimates this influence.

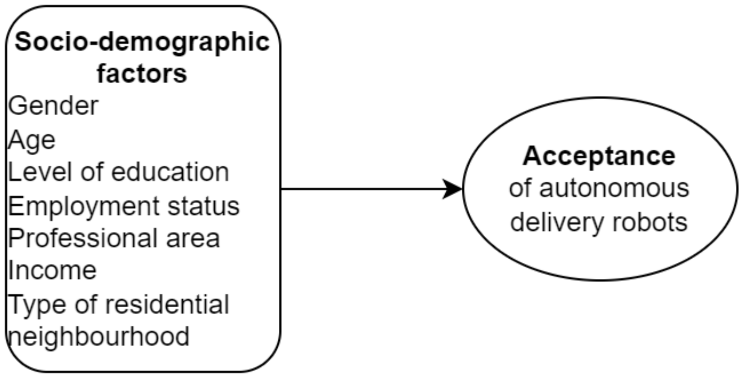

Figure 2: Conceptual model of the influence of socio-demographic factors

A.3. Conceptual model ‘way of grocery shopping’

The conceptual model that serves as a guideline for the conjunct experiment and associated analysis is shown in Figure 3. The choice of having groceries delivered by an autonomous robot or picking up the groceries yourself is believed to be determined by the attributes of shopping and the acceptance of ADRs. Delivery costs and distance to the store (i.e., the attributes of shopping) are included in the model, so that insight is gained into the influence of these characteristics on the choice of shopping.

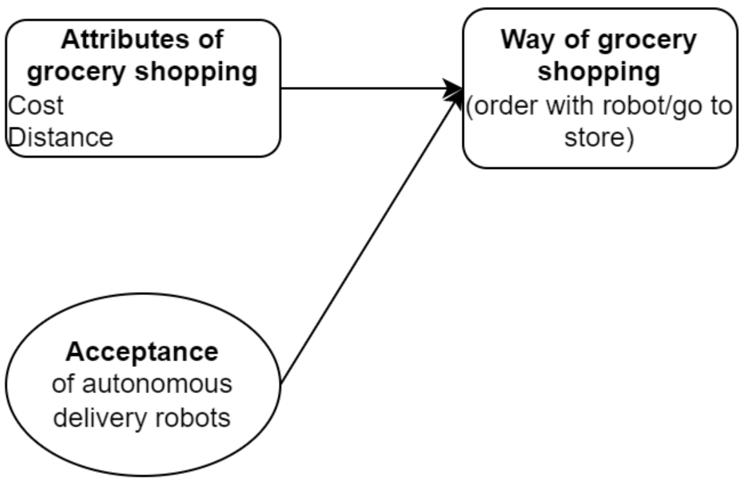

Figure 3: Conceptual model of a way of grocery shopping

Appendix B – Operationalization

The operationalization of the various variables is set out in this appendix. The appendix contains an explanation of how the variables will be measured with the questionnaire. The socio-demographic factors that are included in the survey are discussed in Appendix B.2. Appendix B.3 explains how the acceptance of autonomous delivery robots (ADRs) is measured. Appendix B.4 is about the conjunct experiment with which the demand for ADRs is measured. Additionally, Appendix B.1 elaborates on the population of interest and how a sample is drawn from it.

B.1. Population and sampling

The population consists of all people who live in the Netherlands. The aim is to find out what people living in the Netherlands think of ADRs and whether they accept and would like to use the technology. The data was collected from November 2021 until January 2022 by students of the minor Smart and Shared Cities. The questionnaire was completed by people within the student's network of friends and family. In addition, the questionnaire was distributed by the students through various (social) media channels and on campus Woudestein of Erasmus University Rotterdam by handing out flyers. The sample can thus be referred to as a select, opportunity, or convenience sample and as a snowball sample. The reason for this sampling method is that it has been proven to be the most effective method to reach out to a maximum number of people.

B.2. Socio-demographic factors

Part of the research methodology is to analyse to what extent socio-demographic factors influence the acceptance of ADRs. The hypothesis is that certain demographic factors would indicate the level of acceptance of ADRs. With this information, wider conclusions can be drawn, and further research initiated. Pani et al. (2020) argue that researching different segments of eventual customers can happen by considering different life stages, expenditure patterns, which in this research are called socio-demographic factors and are interpreted in tandem with other statements. Based on a similar study from Lee et al. (2019), that also involved the technology acceptance model, the following socio-demographic factors are included in this research: age, gender, level of education, area of residence, employment status, professional area, and income.

B.3. Operationalization of 'acceptance'

The goal is to measure the acceptance of ADRs. This is done by identifying how people perceive the technology and what their attitudes are towards the technology. Acceptance is a psychologically latent variable and cannot be observed directly. Therefore, ten statements are used. The ten statements are indicators for the underlying psychologically latent concepts. Respondents are asked to indicate to what extent they agree with the statement. A 5-point Likert scale is used for this so that the answers can be quantitatively analysed.

Through factor analysis, it is checked whether the statements fall under an underlying factor or factors and this underlying concept is retrieved (see Appendix E.1). The following ten statements, which relate to acceptance, are used:

1. I think that a self-driving delivery robot can hit me.
2. When I am driving (e.g., by car, bike, scooter), I will fail to see a self-driving delivery robot and hit it
3. I think that self-driving delivery robots invade my privacy.
4. It is a problem that the self-driving delivery robot can only come to the front door and not travel up the stairs.
5. I think it is more difficult to collect groceries when they are delivered by a self-driving delivery robot.

6. I prefer ordering from human deliverers over self-driving delivery robots.
7. I think that self-driving delivery robots will malfunction and not deliver my order on time.
8. I think that if the self-driving delivery robot malfunctions, it will be difficult to contact the support team.
9. I think the ecological footprint of self-driving delivery robots is too high.
10. I do not want to co-exist with self-driving delivery robots in public space.

The following section is a justification of the statements. It highlights similarities between the design of this research and other research conducted regarding autonomous delivery services.

Models to evaluate autonomous systems expand the Technology Acceptance Model (TAM) and Unified theory of acceptance and use of technology (UTAUT) with additional social factors, such as the presence and interaction with the citizens. Henceforth in the research design, elements such as the likelihood to collide with the robot have been considered (statement 1).

The acceptance of the technology in the case of autonomous delivery systems can be different since people can either fully support the technology, or just bear the technology in their environment. To tap into this question, statement 4 of the survey asks respondents directly if they want to see such a technology in the first place.

Abrams et al. (2021) have identified that for the acceptance of the technology warmth (human-like social attributes) and competence are crucial factors. In the survey, statement 8 asks about the user's beliefs about having the robots operating without any flaws and tries to refer to the competence (smartness) factor.

In extensive acceptance models, factors are considered that measure the perceived usefulness for the greater society, not only for the individual. The single point that focuses on the greater picture is the reflection on the perceived environmental impact of the robots (statement 9). Observing this aspect of societal usefulness is the best fit for the currently defined use case of the robot in delivering groceries. This aspect is relatable to the concept of social usefulness that Abrams et al. (2021) introduced, as an expansion to the TAM.

Other parts of the survey reflect on 'traditional' elements of the TAM, with the measurement of the assumed ease of use (statements 4-8). This measure refers to the ease of order collection delivered by an ADR.

Since the Future Mobility Network is leasing the robot from Cartken and cannot change ROSIE's appearance, the appearance of the technology is not measured in the survey. One must keep in mind that appearance also plays a crucial role in the acceptance of autonomous technologies (Pani et al., 2020). Additionally, the interaction aspect of the robot is not measured since delivery technologies are not designed to engage with humans, except when dropping off the package.

B.4. Conjunct experiment

In this section, a choice experiment is set up for grocery shopping. It is a conjunct experiment in which respondents choose between collecting the groceries themselves in the store or having the groceries delivered by an ADR (like ROSIE). The advantage of conjunct measurement with attributes compared to traditional measurement is that profiles can be formed with attributes, which can be weighed up well against each other. The choice experiment is constructed by operationalizing two attributes of the grocery shopping and the dependent variable. With these attributes profiles can then be formed based on a basic plan; this is the experimental design. For this research two attributes of grocery shopping are included: cost and distance.

The first characteristic, costs, concerns the costs incurred for the delivery of groceries by the autonomous robot. This attribute has an absolute zero point and thus is a ratio variable. Despite the fact that two levels would be sufficient to indicate the assumed linear relationship between the cost and choice for delivery, three levels are distinguished. These levels are based on prices that are used in practice or will be used in practice. The cost of delivery is € 0,00 (free) in the first level, € 1,25 in the second level, and € 2,50 in the third level. The first level corresponds with the first month of the pilot with ROSIE on the Erasmus Woudestein campus in Rotterdam, in which deliveries are free of charge. After the first three months, the cost will be € 2,50, which is represented by the third level. The cost of delivery in the second level is comparable to delivery costs of similar services provided by Flink or Gorillas (Gorillas, n.d.; snellesupers.nl, 2021).

The second attribute distance is the distance between the location of the customer and the location of the store from which the groceries can be delivered. This distance is covered by the autonomous robot if it is chosen to order, otherwise, the buyer must travel this distance to go to the store. The levels of this attribute are based on the maximum distance the robot can travel, while delivering in under 30 minutes, and the distance ROSIE travels in practice on the Erasmus Woudestein campus in Rotterdam during the pilot. 500 metres is the distance between the store and the pick-up point on campus and the maximum distance is 1 kilometre. Such as cost, distance is a ratio variable with absolute zero. The expectation is that the choice of having the groceries delivered increases as the distance increases. So, a linear relationship is assumed, which means that the two levels are sufficient. An overview of the operationalisation of the attributes is provided in Table 1.

Table 1: Operationalisation of attributes

Attribute	**Level 1**	**Level 2**	**Level 3**
Cost	Free	€ 1,25	€ 2,50
Distance	500 meters	1 kilometre	-

To construct the profiles, an orthogonal fractional factorial design was used, based on which six profiles were made. Table 2 lists the six profiles used in the questionnaire. The experimental design is both orthogonal and balanced (i.e., all attributes are equally common). Due to the orthogonality, the main effects can be estimated independently of other effects.

Table 2: Profiles based on basic plan 1

Profile	**Cost**	**Distance**
1	Free	500 meters
2	Free	1 kilometre
3	€ 1,25	500 meters
4	€ 1,25	1 kilometre
5	€ 2,50	500 meters
6	€ 2,50	1 kilometre

The dependent variable in the conjunct experiment is the choice for the way grocery shopping is done. There are two options for this: have the groceries delivered by an autonomous robot or pick up the groceries yourself in the store. The dependent variable, therefore, has two levels. The first level is 'I would order from the robot' and the second level is ‘I would pick it up myself’. The conjunct experiment is included in the questionnaire as part 3 (see Appendix C).

Appendix C – Questionnaire

This appendix consists of the questionnaire that is distributed to people living in the Netherlands. The parts 'statements regarding the self-driving delivery robot' and 'choice to let deliver' are respectively based on the operationalization of the psychological factors (see Appendix B.3) and the design of the conjunct experiment (see Appendix B.4).

Introduction

ROSIE (see the picture by Jonathan van Rijn) is an autonomous robot that delivers groceries at Erasmus Campus in Rotterdam. With this questionnaire, we aim to determine your views on automated delivery robots like ROSIE.

The questionnaire will take between five and ten minutes of your time, is anonymous and your privacy will be guaranteed.

The questionnaire consists of three parts:

1. Your background (7 questions)
2. Your opinion about the robot (10 statements)
3. Choice to have groceries delivered with the robot (6 questions)

Thank you in advance for participating in this research!

Miklós Doma, Sanne van Herwijnen, Louis Jørgensen, and Moshiur Rahman

Part 1: Socio-demographic background

Question 1: What gender do you identify as?

- ◯ Male
- ◯ Female
- ◯ Other, _____

Question 2: What is your age? (Fill in as number)

_____

Question 3: What is the highest degree or level of education you have completed?

- ◯ Primary education
- ◯ High school (VMBO)
- ◯ High school (HAVO, VWO) or vocational education (MBO)
- ◯ Bachelor's or college degree (WO-, HBO-bachelor)
- ◯ Master's degree or higher

Question 4: What is your employment status?

- ◯ Employed (for wages or self-employed)
- ◯ Student or in school
- ◯ Retired
- ◯ Unable to work
- ◯ Other

Question 5: What is your professional area?

- ◯ Healthcare and welfare
- ◯ Trade and services
- ◯ IT
- ◯ Justice, security, and public administration
- ◯ Agriculture, nature, and fisheries
- ◯ Media and communication
- ◯ Education, culture, and science
- ◯ Engineering, production, and construction
- ◯ Transport and logistics
- ◯ Not applicable
- ◯ Other, ______

Question 6: What is your monthly net income?

- ◯ Below € 500
- ◯ € 501 - € 1.500
- ◯ € 1.501 - € 2.500
- ◯ € 2.501 - € 3.500
- ◯ Above € 3.501
- ◯ Not applicable

Question 7: Where do you live? (Choose the most applicable)

- ◯ City centre
- ◯ City (not centre)
- ◯ Suburb
- ◯ Town
- ◯ Countryside

Question 8: Do you live in the Netherlands?

- ◯ Yes
- ◯ No

Part 2: Statements regarding the self-driving delivery robot

Are you familiar with automated delivery robots?

- ◯ Yes, I have seen an automated robot drive
- ◯ Yes, I have heard about automated delivery robots before
- ◯ No

Choose the most applicable answer to each of the ten statements below.

Statement 1: I think that autonomous delivery robots invade my privacy.

- ◯ Strongly disagree

◯ Somewhat disagree
◯ Neutral
◯ Somewhat agree
◯ Strongly agree

Statement 2: I think that autonomous delivery robots can hit me.

◯ Strongly disagree
◯ Somewhat disagree
◯ Neutral
◯ Somewhat agree
◯ Strongly agree

Statement 3: When I am driving (e.g., by car, bike, scooter), I will fail to see an autonomous delivery robot and hit it.

◯ Strongly disagree
◯ Somewhat disagree
◯ Neutral
◯ Somewhat agree
◯ Strongly agree

Statement 4: I do not want to encounter autonomous delivery robots in public space.

◯ Strongly disagree
◯ Somewhat disagree
◯ Neutral
◯ Somewhat agree
◯ Strongly agree

Statement 5: It is a problem that the autonomous delivery robot can only come to the front door and not travel up the stairs.

◯ Strongly disagree
◯ Somewhat disagree
◯ Neutral
◯ Somewhat agree
◯ Strongly agree

Statement 6: I think it is difficult to collect groceries when they are delivered by an autonomous delivery robot.

◯ Strongly disagree
◯ Somewhat disagree
◯ Neutral
◯ Somewhat agree
◯ Strongly agree

Statement 7: I prefer ordering from human deliverers over autonomous delivery robots.

◯ Strongly disagree
◯ Somewhat disagree
◯ Neutral

- ◯ Somewhat agree
- ◯ Strongly agree

Statement 8: I think that autonomous delivery robots will malfunction and not deliver my order on time.

- ◯ Strongly disagree
- ◯ Somewhat disagree
- ◯ Neutral
- ◯ Somewhat agree
- ◯ Strongly agree

Statement 9: I think that it will be hard to get help if anything goes wrong with my order.

- ◯ Strongly disagree
- ◯ Somewhat disagree
- ◯ Neutral
- ◯ Somewhat agree
- ◯ Strongly agree

Statement 10: I think that autonomous delivery robots are bad for the environment.

- ◯ Strongly disagree
- ◯ Somewhat disagree
- ◯ Neutral
- ◯ Somewhat agree
- ◯ Strongly agree

Part 3: Choice to let deliver

Lastly, you will be presented with 6 situations, with different delivery distances and delivery costs. Please indicate, what would you do in each situation.

Situation 1:

Cost (of delivery)	*Free*
Distance (between you and the store)	*500 meters*

Given the situation above, what would you choose?

- ◯ I would order from the robot
- ◯ I would pick it up myself

Situation 2:

Cost (of delivery)	*Free*
Distance (between you and the store)	*1 kilometre*

Given the situation above, what would you choose?

- ◯ I would order from the robot
- ◯ I would pick it up myself

Situation 3:

Cost (of delivery)	*1,25 euro*

Distance (between you and the store)	*500 meters*

Given the situation above, what would you choose?

- ◯ I would order from the robot
- ◯ I would pick it up myself

Situation 4:

Cost (of delivery)	*1,25 euro*
Distance (between you and the store)	*1 kilometre*

Given the situation above, what would you choose?

- ◯ I would order from the robot
- ◯ I would pick it up myself

Situation 5:

Cost (of delivery)	*2,50 euro*
Distance (between you and the store)	*500 meters*

Given the situation above, what would you choose?

- ◯ I would order from the robot
- ◯ I would pick it up myself

Situation 6:

Cost (of delivery)	*2,50 euro*
Distance (between you and the store)	*1 kilometre*

Given the situation above, what would you choose?

- ◯ I would order from the robot
- ◯ I would pick it up myself

End of the survey

If you have any questions or comments about the robot, the project, or our research please leave them here. ______

Thank you for participating!

Miklós Doma, Sanne van Herwijnen, Louis Jørgensen and Moshiur Rahman

Appendix D – Qualitative analysis

This appendix contains the qualitative analysis on the acceptance of and market for ADRs. In Appendix D.1 interviews conducted among citizens that have seen ROSIE are the subject of analysis. Appendix D.2 contains the analysis of the qualitative data acquired through the survey. Lastly, Appendix D.3, contains the comparative analysis of ADRs in different industries. This section also includes the analysis of how ADRs are perceived in the news.

D.1. Interview

The interviews are conducted on Woudestein campus Erasmus University in Rotterdam. People who saw ADR ROSIE operational on-site were approached for the interviews. The aim of the interviews is to gain insight into the general opinions of ADRs. The responses were mostly positive and critical at the same time.

From the interview, it can be concluded that ADRs are seen as a technology that is beneficial for delivering food and groceries, specifically late at night or on holidays. The reason for this is that at those moments there might be fewer deliverers that want to work or for safety reasons a not-human deliverer could be preferred. In addition, there was enthusiasm for the technology as it would create new opportunities in the development of autonomous technologies.

It emerges from the interviews that delivery speed is a common concern. It was expressed that ADRs are inconvenient as they travel relatively slow. Moreover, since the ADR used in the pilot does not deliver to addresses further than 1 kilometre, it is found not necessary to have groceries delivered. Furthermore, it can be concluded that people are against the technology, because of fear of job loss. Finally, it emerges that worries about theft and vandalism make people sceptical towards ADRs.

D.2. Qualitative analysis of the survey

The survey allows for quantitative feedback, which is categorised into four distinct groups. Before these categories are discussed it is important to note, that during the analysis it can be concluded that only 13 percent of the respondents has seen ADRs, and some respondents were certain about the unlikeliness of utilising such technology. Hence the following notes should be interpreted with care. However, as being the first responses to a big scale survey in the Netherlands they contain crucial remarks.

Firstly, respondents voiced their concerns about the technology. The delivery range has been mentioned most frequently since people expect a longer delivery range to consider ADRs as an alternative to walking. On the other hand, questions arose about the terrain that such robots can drive for instance unbeaten paths, green areas, or between towns eventually. An additional argument about the technology is the ability to use stairs, elevators to provide a better delivery experience. As the last point, security has been mentioned in contexts like the robot's ability to withstand potential attempts of vandalism, and the system's ability to protect goods transported.

The second topic where comments arose is the potential use cases of the technology, as respondents argued that the delivery is not necessarily a decision of price and distance but also weather conditions, the time of the day, or the need for forgotten items after groceries. Other potential opportunities were highlighted for serving less mobile citizens, and people who have difficulties in lifting heavy items or within buildings like hospitals. Some had concerns and indicated that they can only imagine ADRs in closed territories or industrial sites.

Thirdly, respondents expressed a rather negative sentiment about the sociological influence of ADRs. This is about more and more people losing their jobs in the delivery business and the elimination of the personal connection with the delivery person, which is appreciated by some.

Lastly, the fourth concern respondents mentioned is the suitability of ground delivery robots for the future compared to drones. It is due to the reason that drones are considered to be more flexible and move in a space where it does not pose risks to pedestrians.

D.3. Comparative analysis

Players and technologies in the field of ADRs

Last-mile delivery systems are gaining traction in numerous cities around the world (e.g., cities in the US, Europe, and Asia) (Factors, 2022). Cartken, the technology provider of ROSIE is only one of the companies developing ADR technology, in order to offer more customised solutions to last-mile delivery needs. On the other hand, ADRs are forecasted to specialise in food delivery in dense urban areas (Ueland, 2022). The ADR market is valued at $ 24.3 million in 2019 and is expected to increase tenfold by 2027 (Businesswire, 2022). Starship Technologies, Eliport, and Nuro Inc. offer ADRs and have accomplished to differentiate themselves from Cartken by offering additional features. Starship Technologies operate robots with a 4-mile radius that is twice the distance that the ADR from Cartken is commissioned to. Nuro Inc. does not offer a significant differentiation in terms of technology however, they excel in establishing key partnerships with major corporations such as Walmart, FedEx, and Domino’s. Lastly, Eliport as a European firm enhances regional competition, and their ADRs are promoted to conduct loading and unloading without human interaction (Ueland, 2022). Based on this technology review it is clear that different firms offer similar state-of-the-art technology, which poses fierce competition to the current technology provider, who is not in the leading position in this rapidly growing market. This should concern the Future Mobility Network to evaluate that in the long term it is still the most favourable to stay with the current provider since the market is dynamically changing.

ADRs in news articles

De Havenloods (De Havenloods, 2022), a Dutch news portal introduces ROSIE, as a pioneer solution in the municipality of Rotterdam, in the way of tackling urban mobility challenges with green solutions. Besides the environmental friendliness of such ADR, the municipality expresses its hopes to research the policy-related aspects while operating in a public space. Facto, a Dutch newspaper also highlights that people want to walk less than 250 metres for their groceries, and supermarket chains like SPAR expect this technology to add to the customer convenience in grocery shopping (De Facto, 2022). Trouw, a Dutch newspaper shows that policy advisors are also supportive of the technology, as ROSIE has been perceived to be friendly, and students are in favour of ordering (Trouw, 2022). This is related to research question 1A about how people perceive ADRs. From all the comments it is visible that this emerging technology triggers enthusiasm in both the public and private sector.

Appendix E – Statistical analyses

The statistical analyses are presented in this appendix. Appendix E.1 deals with the factor analysis. The chi-square analysis is explained in Appendix E.2. Appendix E.3 and E.4 contain the linear regression models and the logistic regression models, respectively.

E.1. Factor analysis

In the questionnaire that the respondents completed, there are 10 statements regarding the concept of acceptance (see Appendix B.3 and C). These statements show similarities in variance with each other. With this factor analysis, it is examined whether the statements can be grouped into underlying psychologically latent concepts. These concepts are retrieved in order to estimate the acceptance.

For each underlying psychological latent concept, also called a factor, a composite scale is made based on the propositions and their charges. The factor represents the commonality in the indicators. The advantage of using the scale with the factors compared to the statements is that factors can be used to measure more precisely what needs to be measured. Random measurement errors cancel each other out. In addition, there is more certainty about the agreement between the definition of the respondent and the intended definition of the term, because all sub-aspects are included. This ensures that the measurement is more reliable and has a higher instrumental validity. Because all sub-aspects are included, it is clearer what the differences are between the predictors (i.e., statements). This prevents problems with multicollinearity.

Table 3 contains only eight of the ten statements. The other statements are not included in the factor analysis because their communality is lower than 0,25 or they do not charge high on one of the two factors. The variance of these statements is not sufficiently explained by any of the factors; thus, the charge is negligible. The other statements do load sufficiently on a factor (i.e., they load higher than 0,3 on one factor).

Orthogonal rotation was used in this factor analysis. Whenever possible, orthogonal rotation is preferable to oblique rotation because the factors in orthogonal rotation are independent of each other and therefore the meaning of the factors does not overlap. The factor analysis with oblique rotation shows that there are correlations smaller than 0.5 between the two factors. This indicates that orthogonal rotation can also lead to a simple structure. A simple structure is the ideal structure and is reached if each variable loads high (i.e., preferably higher than 0,7 but minimal higher than 0,5) on one factor or if it fits the indicator well in terms of content, and low (i.e., preferably lower than 0,3) all other factors. Without having to remove extra indicators, the factor analysis with orthogonal rotation yields a simple structure and it is, therefore, possible to apply orthogonal rotation.

Table 3: Results factor analysis

Factor	Statement	Load	Cronbach's alpha
1 'Concerns about ADRs'	4 I do not want to encounter autonomous delivery robots in public space.	0,761	0,617
	1 I think that autonomous delivery robots invade my privacy.	0,664	
	10 I think that autonomous delivery robots are bad for the environment	0,628	
	2 I think that autonomous delivery robots can hit me	0,589	
2 'Usability of ADRs'	5 It is a problem that the autonomous delivery robot can only come to the front door and not travel up the stairs.	0,664	0,484
	6 I think it is difficult to collect groceries when they are delivered by an autonomous delivery robot	0,661	
	8 I think that autonomous delivery robots will malfunction and not deliver my order on time.	0,566	
	9 I think that it will be hard to get help if anything goes wrong with my order.	0,540	

There are clear underlying concepts, as evidenced by the factor analysis. The two factors under which the statements fall can be properly interpreted by assigning labels to them. Statements 4, 1, 10, and 2 load 0,761, 0,664, 0,628, and 0,589 on the first factor, respectively (see Table 3). This factor can therefore be labelled 'concerns about ADRs'. All statements are about what someone thinks of the ADRs. If someone has a negative opinion of the technology or thinks that it should not be operational, he or she scores high on this first factor. The second factor is loaded with statements about the use of autonomous delivery robots, which are statements 5, 6, 7, and 9. These statements score 0,664, 0,661, 0,566, and 0,540 on the second factor, respectively. The higher the score of a statement, the less someone finds ADRs easy to use or useful. The second factor is labelled 'usability of ADRs'.

The average sum score is used for the composite scales. The advantage of the mean sum score is that it can be generalised across samples and that differences in effects with other variables can only be traced back to a difference in the sample. A sum score is also easy to interpret in a regression model. In addition, the scale measures uni-dimensionally and there is one dimension for both factors. The disadvantage of the sum score compared to the factor score is that with the average sum score all positions are weighted equally, while with the factor score the positions with a higher load are given greater weight. The sum score thus leads to a lower validity than a factor score. However, the factor analysis does not lead to extremely high scores on any of the factors, so the weights would be comparable even if factor scores are used.

The Cronbach's alpha indicates to what extent the composite scales are reliable. High reliability means that the statements can be easily combined into one scale. The values for the different dimensions are shown in Table 3. A scale is reliable when it has a Cronbach's alpha greater than 0.7. Then the scale has a high internal consistency and reliability. As can be seen in Table 3, both factors do not meet this indication. Since this is an exploratory study and a Cronbach's alpha of 0.617 (for factor 1) and 0.484 (for factor 2) do not indicate extremely low reliability, they can still be used for the study.

E.2. Chi-square analysis

The sample distributions of the socio-demographic characteristics are reviewed in this section. The following socio-demographic characteristics are included: gender, age, level of education, employment status, professional area, income, and residence. The representativeness is then explored with the use of chi-square analysis. It is important to check for representativeness because the sample is a select convenience sample.

Table 4 shows the sample and population distributions of the socio-demographic characteristics. The sample distributions are based on the data collected with the survey. The sample consists of 213 respondents. The population data is based on data from Centraal Bureau voor de Statistiek (2021a-g, 2022) of the Dutch population.

Table 4: Results chi-square analysis (Centraal Bureau voor de Statistiek, 2021a-g, 2022)

Characteristic	Categories	Sample (%)	Population (%)	Chi-square value	p-value
Gender	Male	42,7	49,7	0,0	0,89
	Female	55,9	50,3		
	Other	1,4	-		
Age	15 years or younger	0,9	15,7	239,0	0,00
	15 – 25 years	45,5	12,3		
	25 – 35 years	10,8	12,9		
	35 – 45 years	8,0	11,9		
	45 – 55 years	16,0	14,2		
	55 – 65 years	16,0	13,5		
	65 – 75 years	2,8	11,1		
	75 years or older	0,0	8,4		
Level of education	Primary education	0,9	8,9	50,7	0,00
	High school (VMBO)	7,0	19,9		
	High school (HAVO, VWO) or vocational education (MBO)	44,1	36,5		
	Bachelors' or college degree (WO-, HBO-bachelor)	26,3	21,8		
	Master's degree or higher	21,6	12,9		
Employment status	Employed	54,6	52,4	68,7	0,00
	Student or in school	40,4	21,4		
	Retired	3,3	20,0		
	Unable to work	0,0	4,3		
	Other	1,9	2,0		
Professional area	Healthcare and welfare	14,6	14,9	77,6	0,00
	Trade and services	10,3	27,9		
	IT	9,9	5,4		
	Justice, security, and public administration	7,5	3,7		
	Agriculture, nature, and fisheries	0,9	2,0		
	Media and communication	5,6	2,3		
	Education, culture, and science	15,5	9,7		
	Engineering, production, and construction	8,5	13,3		
	Transport and logistics	1,4	6,6		
	Other	13,1	14,1		
	Not applicable	12,7	-		
Income	Below € 500	15,5	2,6	185,2	0,00
	€ 501 – € 1.500	16,4	16,9		
	€ 1.501 – € 2.500	20,7	38,6		
	€ 2.501 – € 3.500	21,1	26,5		
	Above €3.501	9,9	15,4		
	Not applicable	16,4	-		
Residence	City centre	17,4	-	-	-
	City (not centre)	29,6	-		
	Suburb	9,4	-		
	Town	42,3	-		
	Countryside	1,4	-		

As mentioned, a chi-square test is used to test whether the differences between the sample and population distribution are significant. The following hypotheses apply to this test:

- H0: There is no difference in the distribution of social demographic characteristic X for sample and population.
- H1: There is a difference in the distribution of social demographic characteristic X for sample and population.

The proportion of men in the sample is lower than in the population (see Table 4). The proportion of women is higher and is therefore overestimated. As seen in Table 4, the chi-square value is 0,0. The associated p-value is 0,89, which is greater than the alpha of 0,05. This means that the difference is not significant and that the distribution between men and women in the sample is equal to the population. The category 'other' is seen as a missing value since only 3 respondents identify themselves in this way and no population data is known.

In the sample and population distribution of age, it is striking that there is a large difference between the sample and the population aged 15 to 25 years. This group is overrepresented in the sample. Ages 45 to 65 are also overrepresented but to a lesser extent. The difference between the sample and the population is significant. This can be seen from the chi-square value of 239,0 and the corresponding p-value of 0,00 (see Table 4). This means that there is a difference between the distribution of age in the sample and the population.

The average education level of the sample is much higher than that of the population. There is a bias in the sample compared to the population towards the higher education levels (see Table 4). The levels 'high school (VMBO)' and below are underrepresented in the sample and the other levels are overrepresented in the sample. The difference between the sample and population distribution is significant with a chi-square value of 50,7 and a p-value of 0,00, so also for age, the sample is not representative of the population.

The group of people who are retired is underrepresented in the sample (see Table 4). The group of students/school-age people, on the other hand, is overrepresented. The difference between the sample and the population is very large, especially for these two categories. The difference between sample and population for the work situation is significant. The chi-square value 687, and associated p-value of 0,00 indicates that the distribution for employment status in the sample is not equal to that of the population.

For the distribution of professional area in the sample, all categories show differences from the population. The 'trade and services' category shows the greatest difference between sample and population. The chi-square value of the professional area is 77,6 and the p-value is 0,00 (see Table 4). The difference between the sample distribution of the professional area, therefore, differs significantly from the distribution of the population. The category not applicable is reported as missing value and not included in the chi-square analysis.

The average income of the sample is much lower than that of the population, as can be seen in Table 4. The category below € 500 is overrepresented in the sample, while above € 3,501 is underrepresented. With a chi-square value of 185,2 and a p-value of 0,00, the difference between the sample and the population is therefore significant. The category 'not applicable' is also not included in the analysis for income, because no population values are known for this.

Finally, no chi-square test was performed for the socio-demographic factor residence. The reason for this is that no appropriate population data is known. Thus, no conclusions can be drawn about the representativeness of residence.

In conclusion, except for gender, all sample distributions are significantly different from the population distribution. These deviations can largely be explained by the way the survey was distributed. This is because this is through the network of the students. That network mainly consists of other university students, who are between 15 and 25 years old and often earn little. Differences in income can probably be explained by the fact that the population distribution is based on the income of a household and the survey is dispersed among individuals.

E.3. Linear regression analysis

The in Appendix E.2 identified sample biases that may affect the acceptance and results of this study. To check whether there is an effect and how large that effect is, linear regression model 1 is estimated in which acceptance is predicted based on the socio-demographic characteristics. Additionally, this model gives insights into how socio-demographic characteristics influence one's attitude towards ADRs. The second linear regression model shows how familiarity with ADRs influences acceptance of ADRs. In each of the linear regression models, use is made of the two composite factors 'concerns about ADRs' and 'usability of ADRs' (see Appendix E.1) for the acceptance (e.g., as a dependent variable).

Table 5: Descriptive statistics factors

Factor	**Average**	**95% Confidence interval**		**Standard deviation**
		Lower bound	**Upper Bound**	
1 'Concerns about ADRs'	2,29	2,205	2,375	0,627
2 'Usability of ADRs'	2,60	2,514	2,676	0,601

The mean of the composite scale 'concerns about ADRs' is 2,29 and of the composite scale 'usability of ADRs' it is 2,60 (see Table 5). This average can be interpreted in the original scale because it concerns an average sum score. For 'concerns about ADRs, a score of 5 means someone has a lot of worries, and 1 means he or she has no worries related to the ADR's effect on privacy, the environment, or safety in public space. The 2,29 average indicates that there are not a lot of concerns about ADRs on average. Regarding 'usability of ADRs', a score of 5 means that ADRs are perceived as not usable, while 1 indicates high usability. This means that on average people find ADRs quite usable. Also, the 95% confidence intervals and the standard deviations of the two factors are shown in Table 5. Both measures are used to describe the distribution. Additionally, the distributions are shown in Figures 4 and 5.

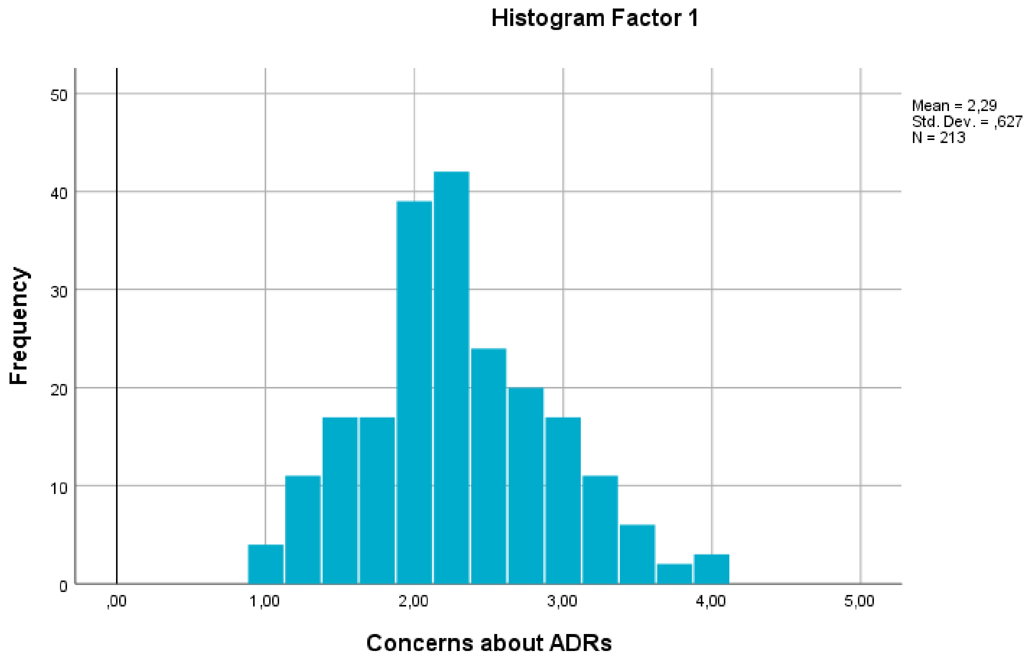

Figure 4: Histogram factor 1 'Concerns about ADRs'

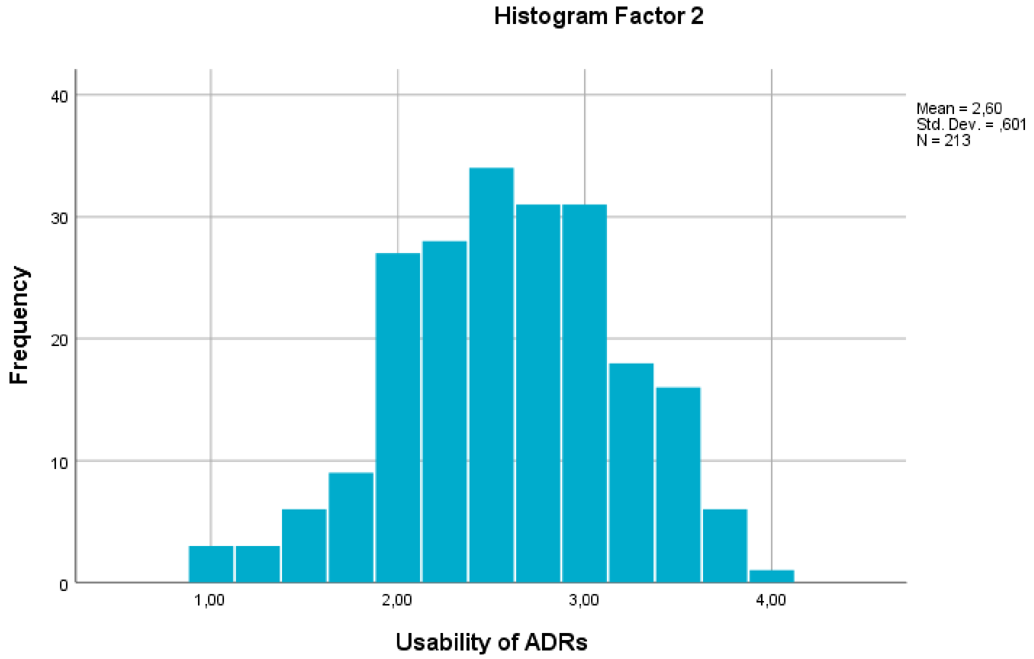

Figure 5: Histogram factor 2 'Usability of ADRs'

Figures 4 and 5 show respectively the distributions of factors 1 and 2. Following the distribution of ‘concerns about ADRs’, it can be concluded that there are people with concerns about ADRs. However, on average people are not very worried and the technology could be used in the Netherlands without problems in the field of acceptance. The distribution of 'usability of ADRs' leads to the finding that there is no one who finds ADRs completely unusable. On the other hand, some people find ADRs extremely usable.

Coding of socio-demographic variables

As is mentioned before, the socio-demographic characteristics are gender, age, education level, employment status, professional area, income, and residence. Age, level of education, and income can be included in the model as continuous variables. The other variables, on the other hand, must be recoded. The reason for this is that education level and income are of ordinal measurement level and age of ratio measurement level. However, there is no clear ranking in the categories for the other variables.

Dummy coding is used to recode the variables. A new so-called dummy variable is created here. The reference category for this new variable gets the value 0 and the category that is compared with the reference gets the value 1. When there are more than 2 categories, several dummy variables are used. The different categories are always compared only with the reference category, which is coded as 0.

Table 6: Dummy-coding socio-demographic characteristics

Characteristic	Category	Dummy 1	Dummy 2
Gender	Male	0	
	Female	1	
Employment status	Employed	1	0
	Student	0	1
	Other	0	0
Professional area	ADR related	1	
	Not ADR related	0	
Residence	City	0	0
	Suburb	1	0
	Countryside	0	1

For the variable gender, the category 'man' is the reference category (see Table 6). The category 'female' is therefore coded as 1. Since there are only 3 cases of the category 'other' in the sample, these cases have been reported as missing values and are not included in the linear regression model.

Dummy coding is also used for employment status. Because the categories 'disabled for work', 'retired' and 'other' have relatively few cases, these categories are combined under 'other'. This leaves three categories that are coded as in Table 6. Employed and students are thus compared with the category of others.

For professional area, the number of categories has been reduced to two. A distinction is made between professional areas that deal with ADRs and the other areas. ADR related includes 'ICT', 'engineering, production, and construction', and 'transport and logistics'. It is checked whether having an ADR-related job affects someone's acceptance of ADRs. The category 'other' is therefore the reference category here (see Table 6).

Finally, dummy coding was used to recode residence. The categories of 'city centre' and 'city (not centre)' have been merged, because the distinction between them is small. Also, the categories 'town' and 'countryside' have been merged for the following reasons. First, there is only a small number of respondents who fall under the 'countryside' category. Second, there is not much difference between the two categories when it comes to using ADRs. The city is the reference category, against which the other two categories are compared (see coding in Table 6).

Linear regression model 1

Table 7 shows the linear regression coefficients of the socio-demographic characteristics and the constants of the model. The coefficients 1 and associated p-values 1 relate to factor 1 'concerns about ADRs'. The coefficients 2 and p-values 2 relate to factor 2 'usability of ADRs'.

Table 7: Linear regression model 1

Variable	Coefficient 1	p-value 1	Coefficient 2	p-value 2
Constant	2,897	-	2,676	-
Gender: Female	-0,077	0,397	0,102	0,231
Age	-0,013	0,450	0,000	0,997
Level of education	-0,011	0,848	0,080	0,148
Employment status: employed	-0,223	0,297	-0,194	0,339
Employment status: student	-0,424	0,098	-0,211	0,382
Professional area: ADR related	-0,082	0,397	-0,095	0,299
Income	-0,052	0,260	-0,036	0,416
Residence: Suburb	-0,210	0,184	0,017	0,909
Residence: Countryside	0,034	0,742	0,261	0,009

Constant 1 of the linear regression models is 2,897. This means that concerns about ADRs has an average value of 2,897 for the reference categories. The reference categories are 'man' for gender, 'other' for employment status, 'not ADR related' for the professional area, and 'city' for residence. The average value of usability of ADRs for the reference categories is 2,676.

Coefficient 1 for gender is -0,077 and coefficient 2 is 0,102. The first coefficient means that the more women there are, the lower the average score for 'concerns about ADRs' is. This would mean that there are fewer concerns among women than men and that women are more accepting of the technology. However, this relationship of the sample cannot be generalised. The p-value is 0,397, which is greater than 0,050 and thus not significant. There is no difference between men and women in concerns about ADRs. The second coefficient is also not significant with a p-value of 0,231. In the sample, women find ADRs on average less usable than men, but this cannot be concluded for the population.

For age, a higher age leads to a lower score for concerns about ADRs. Age does not influence the estimated usability of ADRs. When the age is 1 year higher, the score for concerns about ADRs will decrease by 0,077, while the other predictors maintain a constant attitude. So, the elderly have fewer worries. Because age differences have no significant effect on the factors (see Table 7), the non-representativeness of age does not affect the means of concerns about ADRs and usability or ADRs. Nor can it be concluded that age influences acceptance.

For level of education, coefficient 1 has a value of -0,011, and coefficient 2 has a value of 0,080. This means that as the level of education increases, concerns about ADRs decrease, and the score for usability or ADRs increases, provided the other predictors remain the same. People with a higher level of education, on average, find ADRs less useful. Associated p-values are both non-significant (see Table 7), which means that the associations cannot be generalised to the population. In addition, this means that the educational level is not related to the factors, which means that the bias of the educational level in the sample does not influence the estimate of the means of the factors of the population.

Concerning the employment status, concerns about ADRs decrease if someone is employed or a student rather than retired, disabled, or otherwise (see Table 7). The usability score is also lower on average for students and employees. Retired people, the disabled, and others, therefore, find an ADR on average less useful than workers or students. The negative coefficients have no significant p-value. It can therefore be concluded that the non-representativeness of the work situation has no influence on the averages and that this socio-demographic factor has no influence on the acceptance.

Coefficient 1 for professional area is -0,082 and coefficient 2 is -0,095. The scores for the factors are lower for people with an ADR-related occupation than for the others. The negative coefficients mean that people with an ADR-related occupation score lower on the factors on average. People in ICT, engineering, production, construction, transport, and logistics are less concerned about ADRs, but also find them less useful. This only applies to the sample because the p-values are higher than 0,050.

For income, higher incomes lead to lower scores for concerns about ADRs and usability of ADRs. So, when people have higher incomes, on average they have fewer concerns about ADRs and find the technology more usable. The corresponding p-values are 0.260 and 0.416, respectively. Thus, the negative relationship between income and the factors cannot be generalised to the population. Because the coefficients are not significant, the differences between the sampling distribution and the population distribution of income do not influence the results.

Coefficient 1 of the dummy variable residence: suburb is -0.210 and coefficient 2 is 0.017. This means that people who live in the suburbs generally have fewer concerns about ADRs than people who live in the city. People living in the suburbs also find the ADRs less usable. This only applies to the sample, since the p-values are not significant. People who live in the countryside have more concerns about ADRs than people who live in the city. In addition, people living in the countryside score higher on the second factor on average than people in the city, with a coefficient of 0.260. This second effect also applies to the population (see Table 7). People in the city, therefore, find ADRs on average more useful than people who live in the countryside.

In conclusion, the variables where the sampling distribution is known to be unequal to the population distribution do not have statistically significant coefficients. This means that the biases in the sample do not affect the results of the analysis. The relationship that can be generalised to the population is that between the dummy variable residence: countryside and factor 2; people living in the countryside consider ADRs have higher usability compared to people living in the city.

Coding of familiarity

To determine how familiarity with ADRs affects acceptance, dummy coding is used. Familiarity is of a nominal measurement level. Two new dummy variables are used for the three categories.

Table 8: Dummy-coding familiarity

Familiarity	Dummy 1	Dummy 2
No	0	0
Yes, I have seen an automated delivery robot drive	0	1
Yes, I have heard about automated delivery robots before	1	0

As can be seen in Table 8, the reference category is unfamiliar with ADRs and thus coded as 0 for both dummy variables. This makes it possible to check whether seeing the robot or hearing about the robot influences someone's acceptance. Following the coding, dummy 1 is 'seen ADR' and dummy 2 is 'heard of ADR'.

Linear regression model 2

Table 9 shows the second linear regression model. As in model 1, the coefficients 1 and associated p-values 1 relate to factor 1 'concerns about ADRs' and the coefficients 2 and p-values 2 relate to factor

2 'usability of ADRs'. The independent variables in this model are the two dummy variables of familiarity.

Table 9: Results linear regression model 2

Variable	Coefficient 1	p-value 1	Coefficient 2	p-value 2
Constant	2,320	-	2,625	-
Familiarity: heard of ADR	0,016	0,858	-0,060	0,500
Familiarity: seen ADR	-0,302	0,030	-0,005	0,972

The constant for factor 1 as the dependent variable is 2,320. So, the average score of concerns about ADRs for people who are unfamiliar with ADRs is 2,320. For the sample, the concerns about ADRs are higher for people who have heard of ADRs when compared to people who are unfamiliar with them. For the sample, secondly, the concerns about ADRs are lower for people who have seen the robots when it is compared to people who are unfamiliar with them. This second conclusion also applies to the population. For the reason that the associated p-value is 0,030. In general, it can thus be said that people are less concerned about ADRs when they have seen them. The acceptance is then higher than when people are unfamiliar with the technology.

With a p-value of 0.500 and 0.972, the coefficients for the model with factor 2 as the dependent variable are not significant. The higher average scores of people who have heard of or have seen ADRs for usability of ADRs, therefore, do not apply to the population, while this is the case in the sample. Even though people in the sample who have seen or heard about the robot think the ADRs are more usable, this cannot be said about the population.

E.4. Logistic regression analysis

In this section, the model from the (binary) logistic regression analysis is discussed, and the results of the conjunct experiment are interpreted. In the model, the attributes of shopping and the dimensions found (i.e., factors) of acceptance are included. The logit was used in the analysis and not the odds ratio because it is easier to interpret. There is a linear relationship between the predictors and the logit. The coefficient of the predictors (β) shows the effect on the logit. This means that when a predictor variable increases by 1, the logit increases with the coefficient. The following formula applies to the logit in which this relationship can be seen:

$$logit = ln\left(\frac{p(Y=1)}{1-p(Y=1)}\right) = a + b \cdot X.$$

Binary logistic regression model

Table 10: Results binary logistic regression

Variable	Coefficient	p-value
Constant	-1,508	0,000
Price	1,173	0,000
Distance	-1,735	0,000
Concerns about ADRs	1,497	0,578
Usability of ADRs	-0,079	0,000

The logistic regression model shows the interactions between the main effects; the attributes of grocery shopping and the dimensions of acceptance found (i.e., the factors). Table 10 shows that the factor 'concerns about ADRs' is not significant. This means that the effect does not apply to the population. In the population, 'concerns about ADRs' does not influence the choice of ordering the

ADR or getting the groceries yourself. The attributes price and distance and the factor 'usability of ADRs' do influence the logit of the population.

Table 10 shows that the coefficient of the price is positive. This means that the higher the price of ordering the groceries is, the greater the chance of choosing to pick up the groceries yourself. The chance that someone orders groceries via an ADR is, therefore, greater when the price is lower. This direction is intuitive because you pay for the delivery, but self-collection is always free. Ordering with the ADR is coded as 1 and the alternative to get the groceries yourself with 2. The more positive the logit becomes, the greater the chance of the alternative of getting the groceries yourself.

The coefficients of the distance and usability or ADRs, on the other hand, are negative. The smaller the distance, the greater the chance of the alternative picking up the groceries itself. The chance that people will use the ADR increases if the robot delivers over a greater distance. In addition, the lower people estimate the usability, the greater the chance that they will choose to pick up the groceries themselves.

Results conjunct experiment

Finally, the statistical results of the conjoint experiment are made explicit. Table 11 shows the results for the different profiles.

Table 11: Statistic results conjunct experiment

Profile	Cost	Distance	I would order from the ADR (%)	I would pick it up myself (%)
1	Free	500 meters	20,2	79,8
2	Free	1 kilometre	52,1	47,9
3	€ 1,25	500 meters	5,6	94,4
4	€ 1,25	1 kilometre	23,0	77,0
5	€ 2,50	500 meters	2,3	97,7
6	€ 2,50	1 kilometre	14,6	85,4

Table 11 firstly shows that the proportion of people who would use the ADR is lower when the distance is smaller. This relationship also follows from the logit model. These statistics additionally show how big the difference is between the different profiles. Secondly, Table 11 indicates how the percentage of people that would order from the ADR is affected by the price. A significant drop in the demand can be seen when the price rises from free to € 1,25, while the difference between € 1,25 and € 2,50 is smaller.