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Factors of the Digital Divide in Rotterdam

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Summary

The digital divide has been a new form of social exclusion and has become a popular but controversial concept due to recent technologies, new ways of communication, and new ways of doing business to the point that institutions such as the European Commission, World Economic Forum, and governments have started treating the topic as an indicator of economic growth and societal development. However, due to ongoing technological innovations, digital exclusion is a dynamic process which is difficult to measure and address. Nonetheless, cities continue to digitalize and therefore it is relevant to study who is excluded. The city of Rotterdam is in this process of digitalization and is a particular case of study; the unique characteristics of the city, like its superdiversity and function as the main port of Europe, make the digital divide an interesting topic to study in order to develop valuable tools for policymaking. The Netherlands itself is a country ranked at the top of Europe in terms of digitalization and ICTs, but to measure what is happening in Rotterdam on the city-level, more in depth studies are needed.

This research explores theories and models of measuring the digital divide because the concept is a social topic which implies a complexity that cannot be measured only by access to the internet. The concept has been divided into four levels using Jan Van Dijk's Model of Accessibility to Digital Technologies (ADT) from previous studies in the Netherlands. The levels are Motivation Access, Material Access, Skills Access, and Usage Access. The main objective of this research is to explore the theory of the digital divide and use quantitative data to find the factors which determine the gap in the district of Charlois with a special focus in the neighborhood of Carnisse. This area was selected due to the public sector interest, its low rank in the neighborhood profiles of Rotterdam, and the increasing attention of the municipality in developing the area. With this study, the idea is to create a framework for further studies that can be applied to the rest of the districts to then create a general description of the digital exclusion in the whole city.

Considering the available literature and through the collection of quantitative data, this research conducts econometric analysis and determines that basic demographic factors such as Age, Gender, Education, Income, or Nationality indeed explain the Digital Divide in Carnisse. However, the findings are complex in that some demographic factors determine some of the levels, and others determine other levels. For this reason, an Index of Digital Inclusion was also created to score the neighborhood in the four levels of accessibility.

With its selected methodology and developed survey, this research provides a robust conceptual framework and practical way of measuring the ADT model of Van Dijk. The specific variables selected to measure each level and the methodology of creating the compound variables present a useful tool and a practical way of analyzing the topic for further research in the whole city. As a result of the increasing interest in studying the topic, the public interest in reducing the gap, and the interest in developing the area of Carnise, this thesis is intended to contribute to the lack of studies and knowledge by providing a practical way of measuring the digital exclusion that can lead to clear recommendations for policymakers.

Keywords

Digital divide, demographic factors, social factors, material access, motivational access, skills access, usage access, superdiversity.

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Abbreviations

ADT	Model of Accessibility to Digital Technologies
DD	Digital Divide
CDO	Chief Digital Office
DESI	Digital Economy and Society Index
NRI	The Network Readiness Index
IRT	Item Response Theory
OECD	Organisation for Economic Co-operation and Development
SDGs	Sustainable Development Goals
UN	United Nations

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Chapter 1: Introduction

When discussing topics like Artificial Intelligence, the Internet of Things, Big Data, Machine Learning, Virtual Reality, and Blockchain, among others, the question of accessibility to technology remains one of today's biggest debates (Caradaica, 2020). New models toward sustainable and resilient societies consider ICTs and digitalization as the main axis, to the point that the transformation towards digital economies is considered a preeminent indicator of economic growth and social change.

Since 2014, the digital progress of members of the EU has been monitored by the European Commission in order to build a sustainable, resilient, and fair place for future generations (DESI, 2021). The Netherlands has not lagged in its digital development and is now one of the best-performing countries in the EU with 80% of 5G network coverage in populated areas (DESI, 2021). However, there are still parts of Dutch society that continue to be excluded and are missing the benefits of digitalization. This research aims to analyze that digital gap known as the Digital Divide (DD) by first understanding the concept in the Dutch context, followed by an in-depth statistical analysis of the factors that describe the problem specifically in the city of Rotterdam.

At a country level, the Netherlands with its Digital Agenda sets a precedent and a forward path in terms of digital development; currently, the agenda includes actions to strengthen the Dutch economy in areas such as education, knowledge and innovation, open and high-speed infrastructure, security and trust, greater scope for entrepreneurs and the digitization of sectors (Ministry of Economic Affairs, 2016). This approach and the continuing development describe a positive status quo and have allowed the country to be at the top of international rankings that somehow measure the digital divide.

Additionally, Rotterdam has some specific initiatives to deal with the digital divide from an educational perspective, offered in the form of programs conducted by the Central Library (Bibliotheek Rotterdam) to instruct digitally-excluded people on using digital government services and other tools (Digisterker and DigiVitaler). The city also has initiatives related to a digital economy with the smart port and plans for smart industries. Nonetheless, the city does not have a policy or clear strategy to tackle the divide; moreover, there is no data available to describe the current situation of the city. In order to create a policy, it is necessary to describe who is excluded, where these digital illiterates are found, and why and on what grounds they are excluded. In collaboration with the Rotterdam Chief Digital Office (CDO), this research aims to define and provide a framework of the factors which describe the digital divide in one district of Rotterdam, for the development of several initiatives in the area. This thesis was developed for the district of Charlois with a special focus on the neighborhood of Carnisse, due to direct interest of the CDO office of the Municipality of Rotterdam and due to low scores in its neighborhood profile (Wijkprofiel).

The factors to describe the DD can range from simple demographic characteristics such as age, ethnicity, income, age, and gender, to more specific characteristics of digital use and skills. In this research, an overview of the different conceptualizations and measurements of the digital divide will be made, as part of a method to describe specifically the situation in Carnisse. The model of accessibility to digital technologies (ADT) presented by Van Dijk (2006) proposes a linear model based on different levels, starting from a motivational level, then a material level, later to a skills level, and ending with a usage level. This model describes phases of digitalization in terms of four variables, which are the variables used to test using econometric analysis of the quantitative data collected in this study.

The data to conduct this research was collected by the Digital Divide group of students jointly with the CDO department of the Municipality of Rotterdam. The data is from a survey questionnaire where the four main variables of the ADT model were measured by self-reported information of a representative random sample of Carnisse's population. With this research, the idea is to study the problem and provide the framework for the municipality for the later expansion of the methodology to the rest of the city, and for the development of policies related to the reduction of digital inequality in order to support the neighborhood's competitiveness. Additionally, this research supports the current initiatives of development in the area and brings a clear panorama of what the municipality and public institutions are dealing with.

1.1. Objectives

As mentioned, the main objective of this research is to define what is the digital divide in the context of Rotterdam, but also to describe who, where, why, and on what grounds are Rotterdam's inhabitants excluded. However, to describe in detail the main objective, the following sub-objectives are presented:

- Define the digital divide for accurate measurement in Rotterdam.
- Identify what level of the digital divide is more present in Rotterdam.
- Describe which determinants define the digital divide in Rotterdam.
- Find the demographic and social characteristics of the people who are digitally excluded.
- Assess the influence of these factors in the increase of the digital divide.
- Recommend what factors should address the policies targeting the digital divide in Rotterdam.

With the first sub-objective, the purpose is to analyze the literature and conclude which definition and type of measurement is better to describe the Digital Divide for Rotterdam, considering the specific context. With the second objective, the idea is to investigate which level of the ADT model is more present in Rotterdam, based on the performance of the country in digitalization and considering the collected data. The third, fourth, and fifth objectives aim to identify, using regression analysis, the factors or characteristics of the populations that increase the gap of exclusion. The final sub-objective is to present a summary of the conceptual and statistical analysis of the specific status quo of the digital divide in Rotterdam.

1.2. Research Questions

This thesis aims to investigate the specific factors that describe and determine the digital divide in Rotterdam. With the purpose of unmasking the problem in the city and recommending some key points that policies should address, the main question of this research is:

Q. What demographic and social factors explain the digital divide in Rotterdam?

To answer this, the following sub-questions are proposed in a logical order moving from understanding the problem to the specific analysis of factors:

Q1. What are the most applicable models to define and measure the digital divide in the context of Rotterdam?
Q2. Considering demographic and social factors, who is digitally excluded in Rotterdam?
Q3. What social and demographic factors explain each of the levels of the digital divide (Motivational, Material, Skills, Access) in Rotterdam?

The objective of these questions is to start firstly with a general understanding of the different definitions and ways of measuring the concept, in order to define which variable or variables can be used as dependent variables for this research. Secondly, creating, according to literature reviews and secondary data, a profile of the population exposed to the phenomenon. Literature suggests that low income, low education, and the elderly are the most exposed to digital exclusion; despite this, the specific case study of Rotterdam could have different outcomes based on other indicators like ethnicity, employment, or language. Finally, answering which of the factors, whether age, gender, income, education, employment, or nationality, among others, explains each of the levels of the ADT model (Motivational Access, Material Access, Skills Access, and Usage Access).

As a result of this process, the literature in the field, and consideration of the Dutch context, potential hypotheses would be:

- **H.1** The demographic characteristic of ethnicity is highly significant explaining the Digital Divide of Rotterdam.
- **H.2** Higher levels of education are related to low digital exclusion.
- **H.3** Age is highly significant explaining the digital divide in the level of motivation; the older the person, the more excluded from technologies.
- **H.4** High income is related to more access to digital devices.

1.3. Scope and Limitation

In terms of scope, this research is focused on the factors which determine the gap between those who are digitally included and those who are not. The study of the factors is done using quantitative analysis of the collected data. The quantitative-only approach somewhat limits the analysis; including a qualitative part could have provided a more in-depth understanding of the reasons for the findings. Nevertheless, this research is part of a broader study with the Digital Divide group that addresses other aspects of the topic using other approaches. Additionally, the quantitative focus is supported by the intentions of the CDO office of the municipality of Rotterdam on understanding and describing the problem in Rotterdam.

This research is limited by the sample size, time of the investigation, the lack of information from previous studies about the topic in Rotterdam, as well as the self-reported method of the collected data. In terms of the sample size, Rotterdam is a city with 655,106 inhabitants (Municipality of Rotterdam, 2022); getting a random representative sample of the entire city would imply extensive work of data collection, therefore, the research proposed the analysis of the district of Charlois with special focus on the neighborhood of Carnise as a pilot plan to test the tools (questionnaire and models of analysis) to later enlarge the study to the rest of Rotterdam. The selection of Carnisse as a focus area is due to the characteristics of the neighborhood such as a smaller population of 11,849 inhabitants (2021) and the lowest scores of the neighborhood profile indexes (Wijkprofiel Rotterdam) with 66 in the social index, 85 in the safety index, and 87 in the physical index. Moreover, it was motivated by the clear interest of the CDO office and the municipality, both in general, and in developing a platform called Us Carnisse (Wij Carnisse) for integration of society and growth of the area. Regarding the time, this research collected cross-sectional data, which can be used for econometric analysis, but for a better understanding of the DD, a collection of data across time (panel data) would be beneficial.

Finally, the self-reported method of data collection was selected due to the nature of the concept. It measures indicators like motivation, skills, and usage, based on an individual's self-reported answers. This model is an alternative to running practical or operational digital tests

which may be more accurate than self-reporting. For this reason, the questionnaire was created using scales and multiple options to limit different responses and to control exaggeration of results.

1.4. Thesis Structure

This research follows the following structure:

I. Chapter 1: Introduction. This section introduced the main topic and the problem. Additionally, it outlined the objectives, the research questions, the hypothesis, and the scope and limitations.
II. Chapter 2: Literature Review. This section presents a discussion of models which define the topic in different ways and levels, and later presents the one used for this study, criticizing it and discussing methodologically how it is done.
III. Chapter 3: Research Design and Methodology. This section presents the research strategy, the sample size, the reason for selecting Carnisse, the operationalization of the variables and indicators, the explanation of the data collection method, the analysis techniques applied, and the validity and reliability including the limitations.
IV. Chapter 4: Results and Analysis. This chapter presents first a description of the data collected, second an analysis of the summary statistics, third an analysis of the compound variables, and ends with an analysis of the digital divide index.
V. Chapter 5: Discussion. This section presents the main debates found in the thesis and compares the results with the literature. Also, presents potential ideas for future studies.
VI. Chapter 6: Conclusions. The final section of the thesis briefly presents the findings and main takeaways of the study. Also provides potential policy recommendations according to the findings.

Chapter 2: Literature review and hypotheses

The digital divide is commonly defined as the difference separating those persons who have access to new technologies from those who do not (NTIA, 1999); it is a concept that remains ambiguous and its origin is somewhat uncertain, to the point that many comments have been published criticizing and arguing that the divide is a myth, it is a political hyperbole, bunk, non-existent, or rubbish (Grunkel , 2003). However, the question is whether it has stretched or shrunk, and what is going to happen in the upcoming future. According to the general characterization of the concept, it is well known that access to technology is not the only approach or determinant, due to the fact that technology is limited by certain circumstances. Beyond access, people need to know how to employ it and use it. In the end, the DD is a complex and dynamic phenomenon (van Dijk & Hacker, 2003).

The lack of specific quantitative data describing the current conditions of the digital divide in Rotterdam and the need to create a local strategy for digital development make the study of the subject significant and necessary. Even though there are European statistics for the member states, like the Digital Economy and Society Index (DESI) by the European Commission and The Network Readiness Index (NRI) by the World Economic Forum, which are both considered as drivers for the Digital Agenda of the Netherlands, there are no indicators related to the topic that can be used to develop policies and strategies at the local level.

In order to achieve this, conceptualizing the digital divide in a city-specific context is the first step. Understanding Rotterdam as a superdiverse city, referring to its status as a city with an accumulation of migrant groups and variations of other dimensions like religion, socio-economic status, languages, etc. (Scholten, Crul, & van de Laar, 2019) is one of the main issues to consider when studying the digital gap.

First, the OECD defines the digital divide as an existing gap between individual, households, businesses, and geographic areas at socio-economic levels regarding the opportunities to access ICTs and the use of internet (OECD, 2001); this bivariate concept of access and usage depending on socio-economic factors gave a preliminary picture on how to measure the DD. Moreover, the OECD also presents socio-economic factors like income as an important determinant of access, education as an explanation of access, family structure making a difference also in the access, age and gender playing a role in both access and usage, ethnicity as an access factor but related to income and education, language as a factor of usage, and a difference of location between urban and rural (OECD, 2001).

In the same line, a similar definition of the digital divide as a gap between individuals with ready access to ICTs and the knowledge required to access them, and considering socio-economic, geographical, educational, attitudinal, generational factors or physical disabilities as determinants of the divide (Cullen, 2001). This one also presents the concept with two variables, but in the form of access and skills. Moreover, it also considers demographic factors as determinants, but includes attitudes as a factor on measuring the DD. Additionally, it introduces the potential barriers of internet usage with four key issues: physical access, skills, attitudes, and the content. Further models, which are the main pillar of the methodology of this research, consider these barriers as part of the conceptualization of the digital divide.

Later, in the Dutch context, the digital divide is defined as a dynamic continuous shifting phenomenon, but in terms of skills and usage, leaving aside the access (van Dijk & Hacker, 2003) At the same time, it refers to a concept first introduced by Van Dijk in 1999 where access is considered as a concept with four edges or barriers: first, lack of elementary digital experience caused by low interest, anxiety, and unattractiveness of technology (Mental Access); second no possession of computers and connectivity (Material Access); third, lack of

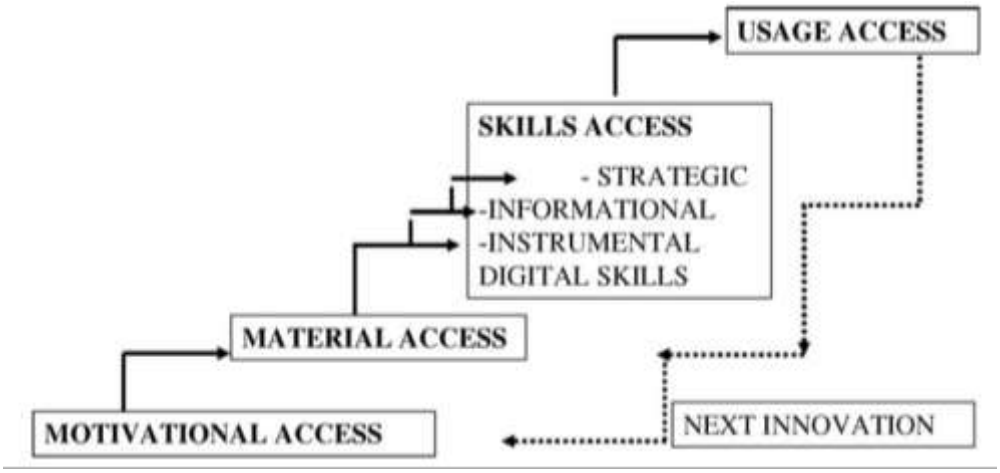
skills caused by low education or social support (Skills Access); and lastly, lack of significant opportunities to use (Usage Access) (Van Dijk, The network society, Social aspects of new media., 1999). It also presents basic demographic factors such as Age, Gender, Income, and education as determinants of the gap.

Subsequently, Van Dijk (2005) refurbished the concept of barriers to accessibility into the creation of the model of Access to Digital Technologies (ADT) to extend the concept with a multivariate approach, with four levels of accessibility to the technological world; first a motivational level, followed by material access, skill access, and ending with usage access, leading to digital inclusion when the process is completed. This model changes the perspective of mental access to motivational access and give a conceptual framework for each variable or level (Van Dijk, 2005).

The digital divide is currently understood on three levels, based on the trends of the understanding of the definition. Conceptualized between 1995 and 2005 with a binary division between those with physical access or not to the internet is the **first level**, providing a partial and limited picture of digital inequalities (Ragneda & Kreitem, 2018); later from 2004 to 2015, the **second level** is considered with the introduction of need of the digital skills to effectively use the technology; finally, from 2015 to date, the **third level** underlines the possible outcomes referring to who gets the most out technology (Scheerder, van Deursen, & van Dijk, 2017). The Van Dijk model of access to technology, which also represents a model of social inclusion, can be described with these three levels; however, motivational access gives a broader vision for multivariate analysis of determinants of the digital divide, and usage access can lead to different possible outcomes, meaning that it addresses the third level of the DD at an early stage. Even though the model was presented in 2005, it provides a full explanation of digital inclusion that is presently applicable.

As shown though the development of the definitions, the first concern of the digital divide is access, but because of the complexity of the problem, a bivariate conceptualization is not accurate and leaves aside many considerations. The inclusion of more variables to define and to measure the existing gap is needed in a modern city such as Rotterdam considering the existing technological advances. To explain the ADT model in more detail, Chart 1 shows the conceptual framework developed by Van Dijk to overcome the limited bivariate vision of the concept.

Chart 1. Model of Access to digital Technologies (Van Dijk, 2005)



Source: (Van Dijk, Digital Divide research, achievements and shorcomings, 2006, p. 4)

In this model, motivational access refers to the desire to have a computer and to be connected to internet. Material access refers to physical access to computers and the internet. Skills access

is the knowledge required after getting motivation and material access. And finally, usage as the final goal of the process that considers time, type of applications, and broadband or narrowband use (Van Dijk, 2006). This model provides specific determinants to consider when analyzing the DD, in addition to the classic factors, and these determinants can be considered as the sub-variables that define each level of the ADT model.

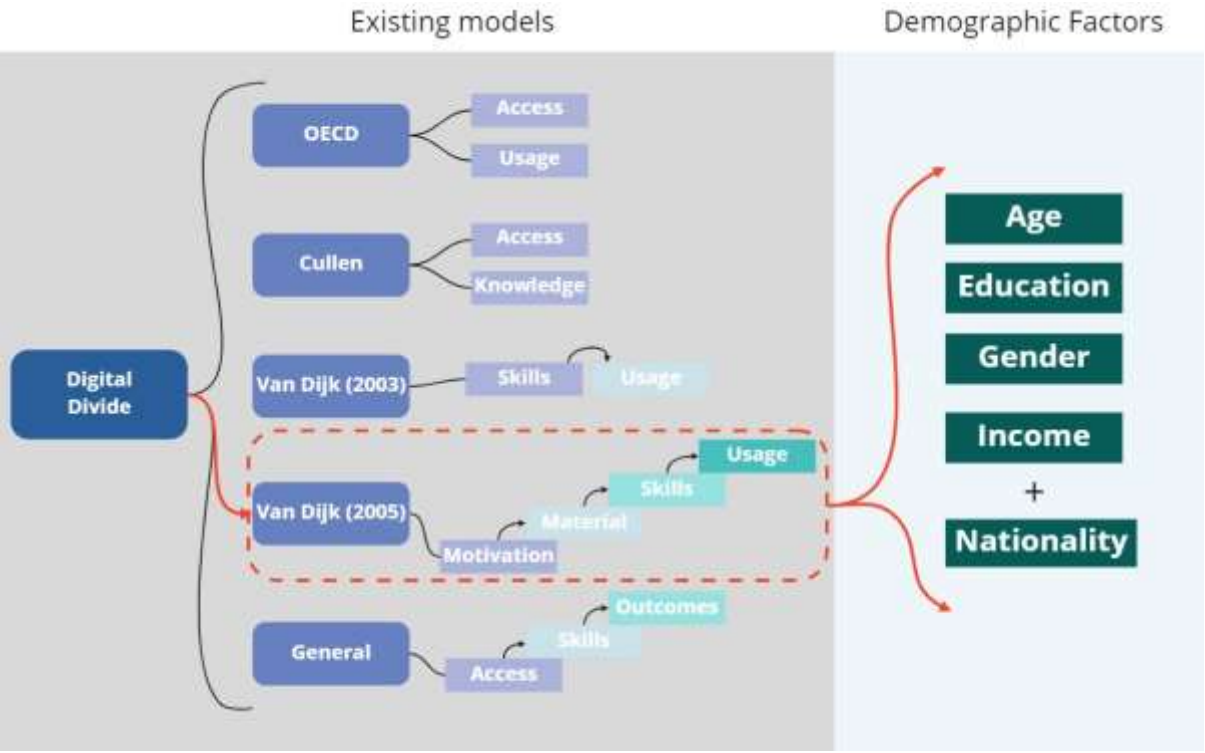
In terms of the applicability of this model, it fits the context of Rotterdam because it considers a more in-depth analysis of the topic that comes closer to what is necessary to describe social behavior in a complex and diverse city. On the other hand, this model is linear and can fall short due to the fact that it is accumulative, and it raises levels in the form of steps; for example, in order to reach the skills access, the motivational and the material access must have been achieved. This linearity, although logical, presents only one possible pathway of being digitally included, falling into a deterministic approach. In Chapter 5, this is discussed further through the obtained results and other methodological findings.

Besides this critique, the model also presents the determinants of each one of the levels, offering specific variables to study. For Motivation Access, the model mentions social, cultural, and mental or psychological determinants in the form of anxiety. For Material Access, it provides the determinants of computer access and internet access. For Skills, the relevant determinants are computer skills, instrumental skills, strategic skills, and information skills. For Usage Access, the model proposes the determinants of usage time, usage applications, broadband or narrowband use, and creative use (Van Dijk, 2006). Certainly, to measure these determinants, they must be transformed into applicable questions in the form of a survey or test, and they need to be revised considering the current reality and context of the case study of Carnisse. For this research, the mentioned determinants were altered to include more variables and adjustments to those proposed by Van Dijk, in order to create a more practical and applicable form of the model for easy measurement in Rotterdam and similar cities.

On the other hand, when referring to the factors which are the main purpose of this thesis, classical demographic characteristics were presented in each of the existing models of conceptualizing the DD, the most common factors that are repeated in every model are gender, age, education, and income. Additionally, because of the strong association between digital exclusion and traditional forms of social exclusion (Van Deursen, 2010) the same factors considered in other form of social exclusion can also be used. Moreover, when considering the specific city context of Rotterdam as a superdiverse city due to the entrance of many different types of migrants, meaning 1st, 2nd and 3rd generation migrants (Scholten, Crul, & van de Laar, 2019), the factor of ethnicity is also relevant in the measurement of the digital divide.

The methodological explanation of how this research reformed the ADT model by including more measurable and practical variables, and the construction of the compound variables to mix the variables and evaluate each level are explained in detail in Chapter 3. The final outcome of obtaining a score of the DD of Carnisse based on the ADT was done with the creation of a model, also explained in the following chapter. The following conceptual framework shows how this thesis was constructed considering the chosen conceptualization of the Digital Divide.

Chart 2. Conceptual Framework



Source: author, 2022.

Chapter 3: Research design & methodology

This chapter translates the theoretical findings into indicators to measure the digital divide. As mentioned above, for this measurement, the concept is divided into the levels of the accessibility to technologies model (ADT) of Van Dijk (2005). From this model, the main concepts are extracted and divided into variables that allowed their study and analysis. Section 3.1 of this chapter reviews the strategy of the research, Section 3.2 the sample size and the selection of the district of Charlois and more over the importance of Carnisse, Section 3.3 reviews the operationalization of the four levels and ends with demographic factors and social inclusion factors, Section 3.4 reviews the method of the data collection, Section 3.5 the data analysis techniques, and finally Section 3.6 reviews the validity and reliability of the research with a special focus on the limitations of the data collection.

3.1. Research Strategy

Regarding the strategy of the research, this paper is an exploratory investigation using the case of study the neighborhood of Carnisse due to several reasons explained later in this chapter. The objective is to define and describe using quantitative data the digital divide in the neighborhood in the context of Rotterdam. To achieve this, the research was planned first starting with a literature review about the topic, choosing a definition and model to measure the division, a collection of data using a questionnaire, an analysis of the data, a creation of a Digital Divide index with the data, and finally a discussion to support the findings.

The collection of the data was done through a questionnaire of eight sections that measure each level of the ADT model, finance, labor, municipal and demographic information. It is a survey with the modality of self-reporting questions, with answer scales from 1 to 5 according to the level of agreement. This survey was conducted face-to-face in urban areas and centers of communal meetings of Carnisse.

For the analysis, the data collected through the survey was revised first with basic summary statistical analysis to describe the data, and later analysis of the compound variables created for each level of the ADT model. The creation of each compound variable is explained in Section 3.5 of this chapter. Additionally, with the compound variables for each type of access, an Index of the Digital Divide was created to represent the overall value of digital inclusion of the neighborhood of Carnisse.

Finally, econometric analysis was applied using the compound variables, the index, and the demographic factors collected in the survey; these results are discussed and debated in Chapters 4 and 5.

3.2. Sample Size and Selection

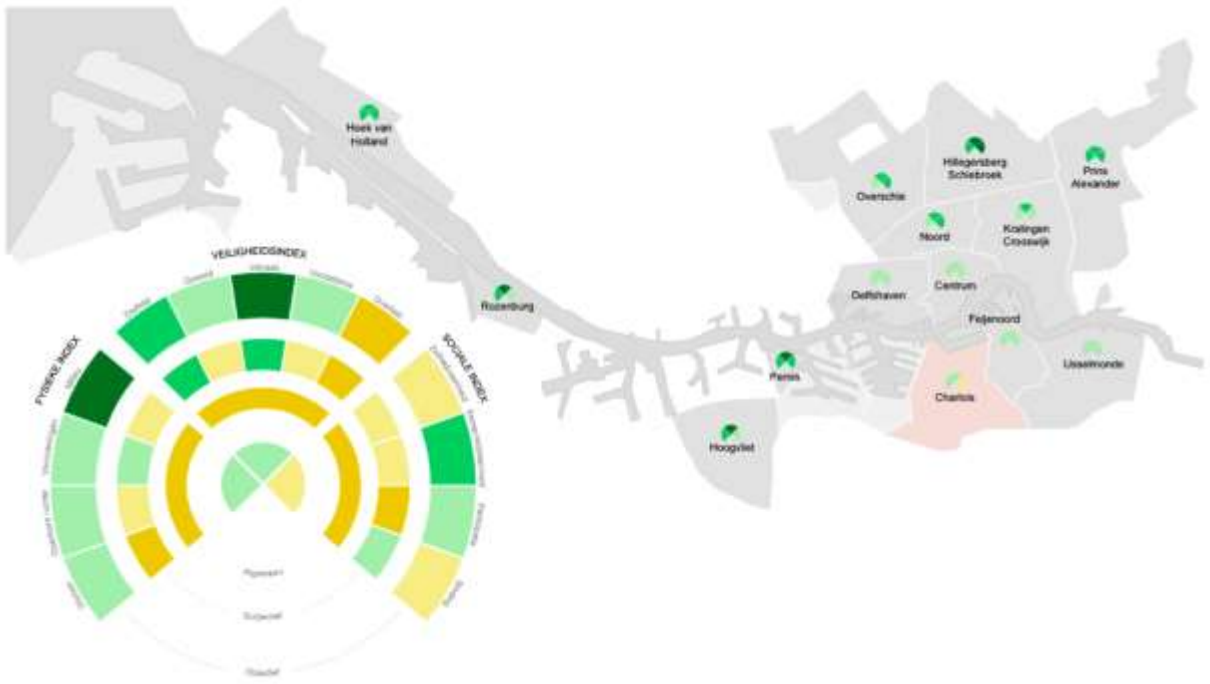
For the data collection, the size and the selection of the sample were based on two essential principles that justify this study: the number of inhabitants and the importance according to the public interest from the Municipality of Rotterdam specifically from the CDO office. Additionally, the neighborhood was selected for the data collection as a pilot plan to evaluate the survey for later application to the rest of the city.

The selected neighborhood was Carnisse in the district of Charlois in the south of Rotterdam. Regarding its geographical characteristics, Charlois has a population of 69,740 inhabitants (2021) in an area of 11.36 km2, and specifically, the neighborhood of Carnisse has a population

of 11,849 inhabitants with a total of 6.512 households and a total of 5.974 residences, mainly of 2- and 3-room houses, which means an average of one or two-person households (Municipality of Rotterdam, 2022).

The reason for the selection of Charlois is due to its neighborhood profile, where the district (as shown in Figure 1) compared to the rest is the one with the lowest levels in the indices. As seen on a general level, the social, safety, and physical indices are presented in a yellow color with scores of 53 for judgment of the quality of life, 64 for safety experience, and 38 for living experience, demonstrating that Charlois's development has been left behind compared to the rest of the city.

Figure 1. Wijkprofiel Rotterdam, Charlois.



Source: (Municipality of Rotterdam, 2022)

In more detail, the importance of Carnisse is due to this low development. As shown in Figure 2, Carnisse has, among all the neighborhoods in Rotterdam, the lowest social index score in 2020. Additionally, in the same figure the *horseshoe graph* (*hoefijzer)* shows the scores for 2022, showing at a general level the safety and physical index in light-yellow, meaning values between 70 and 89 in the index scale, and for the social, in dark yellow meaning values less than 69 in the index scale. Based on these figures, the social factor in Carnisse is critical, and elements such as the experience of quality of life, self-sustainability, co-reliance, participation, and bond among the Carnisse population present an overall low value of 66 (Municipality of Rotterdam, 2022).

Figure 2. Wijkprofiel Carnisse, social Index 2020.

Source: (Municipality of Rotterdam, 2022)

Moreover, because of the public interest in developing the area due its lowest ranks in the municipal neighborhood profile, the CDO office has already begun some initiatives to develop programs targeting improvement of quality of life and participation of Carnisse. A project called "Wij Carnisse" (Us Carnisse) is in progress, in close cooperation with the neighborhood team, the stadsmarinier, and Maljaerd den Hollander (District Manager). "Wij Carnisse" is currently being developed to create a platform to connect and inform the population about municipality services, benefits, and social activities. Certainly, Carnisse is a place with immense potential for development and the application of this study in the area supports the work that is already being done in the area.

Concerning the sample size, statistical methods were used to determine the size using Carnisse's population. Specifically, the Yamane (1967) formula was used:

$$n = \mathrm{N} / (\mathrm{N}.\mathrm{e}2 + 1)$$

Formula 1. Yamane

Where n is the sample size, N is the total population and e is the marginal error. For this research, a marginal error of 10% was considered, contemplating the limitations of data collection described in section 6 of this chapter. Thus, the sample size was calculated as follows:

$$n=11849 / (11849x0.1x0.1 +1)$$

$$n=11849 / 119{,}49$$

$$n=99{,}16 \cong 100$$

Furthermore, as this research applies econometric methods of multiple regression analysis, the sample had to meet the basic assumptions of these models, meaning the sample must be random in a population of +18 years old. In addition to this, and due to the collection method, it was assumed that there would be limitations to response completeness, so more data was collected than necessary to guarantee greater representativeness and better robustness of the study.

3.3. Operationalization: Variables, Indicators

Measuring a concept such as the digital divide is complex due to the dynamism of constantly changing technology. However, first clearly defining the concept allows for measurement. For this reason, the four levels are outlined as an intelligible way to measure this issue considering the limitations present in the study. The following is the operationalization of the four levels of the digital divide, along with their measurement indicators.

Motivational Access

First, the motivational access refers to the wish to have a computer and the desire to be connected to the internet (A.G.M & van Dijk, 2006). The motivation as a personal self-reported measurement in the survey could be a subjective topic, nevertheless, it was measured in terms of the agreement with a scale from 1 to 5, where 1 was strongly disagree and 5 strongly agree. This variable was measured using three variables; the level of stress or anxiety about using devices and/or the internet (stress), the improvement of life due to the access to the internet and to digital devices (improvement), and the increment of knowledge because of the internet (knowledge).

Material Access

Material access refers to the possibility of society having access to the internet and to digital devices such as computers, smart phones, or tablets. As reviewed, internet access is what is normally measured in indicators such as DESI or RNI, and based on that, those indicators consistently place the Netherlands in the top compared to other European countries, due to new policies related to smart cities and improvement of telecommunications infrastructure. However, internet access falls short of measuring the digital divide because it is an individual social concept that although a user has access to the internet, this does not mean that he/she will be able to use it if he/she does not have a connected device. Therefore, in this research the concept of material access is operationalized into four sub-variables: availability of electronic devices, number of devices at home, internet access at home, and internet access in other places such as work/school or transportation.

Skills Access

After being motivated and having material access, one has to learn how to use the devices (A.G.M & van Dijk, 2006). The skills to use the internet or to use a specific device can vary from operational skills or strategic skills to more elaborated, like content creation and software skills. Whatever the case, mastering the skills is what prevents people from falling into the DD. Which skills should be considered to study the DD and how to measure them is still a debate that many scholars are addressing. For this research, the Skills Access was divided into five types of skills: operational, information seeking, content creation, safety and security, and problem solving. Each of these categories has their own variables that aim to measure the concept.

Usage Access

Usage, the last level, is the ultimate goal of the model where after being motivated, having the devices, and knowing how to use them, the next step is how often do people use the technology. This variable was measured with two principles of usage: the usage time of internet and programs, and the purposes of usage.

The following table summarizes all the sub-variables that create the four levels; as explained in Chapter 2, the ADT model poses specific determinants to measure every level, but they fall short considering the current reality and the context of the case study of Carnisse. Therefore, the operationalization includes additional and altered indicators as outlined here.

Table 1. Operationalization table

Concept	Indicators	Data Type	
Motivation & Attitudes	Level of stress/anxiety using digital devices and/or the internet	Categorical 1-5	Ordinal
	Belief that access to internet/digital devices has improved personal life	Categorical 1-5	
	Belief that personal knowledge has increased because of the internet	Categorical 1-5	
Material Access	Types of devices at home	Binary	
	Number of devices at home	Continuous	
	Access to internet at home	Binary	
	Access to internet at other locations (home, work/school, traveling, other)	Binary	
Operational Skills	Connect to wifi	Binary	
	Look for info with search engine	Binary	
	Install apps on mobile device	Binary	
	Download and retrieve files	Binary	
	Attach file to email	Binary	
	Complete online forms	Binary	
	Avoid computer viruses	Binary	
Information Seeking Skills	Deciding best keywords for online search	Categorical 1-5	Ordinal
	Navigating websites	Categorical 1-5	
Software & Content Creation Skills	Change settings on device/application	Categorical 1-5	Ordinal
	Find, download, install, configure applications	Categorical 1-5	
	Produce or edit content with word processor	Categorical 1-5	
	Produce or edit spreadsheets	Categorical 1-5	
	Use basic formulas in a spreadsheet	Categorical 1-5	
	Create digital presentations	Categorical 1-5	
	Produce or edit simple digital content (images, video, audio)	Categorical 1-5	
	Use specific software for design, calculation, and/or simulation	Categorical 1-5	
Safety & Security Skills	Check if information and websites are trustworthy	Categorical 1-5	Ordinal
	Know which information should/should not share online	Categorical 1-5	
	Feel safe sharing information online for municipal services, subscriptions, etc.	Categorical 1-5	
Problem-Solving Skills	Ability to solve routine problems with devices	Categorical 1-5	Ordinal
	Ability to find support/assistance when problem occurs	Categorical 1-5	
Digital Usage	Email address	Binary	
	Frequency of internet usage	Categorical 1-6	Ordinal
	Frequency of application/software usage	Categorical 1-6	
	Types of usage (media, gaming, leisure search, practical search, online course, news, job search, online shopping, product reviews, social networks, sharing photos/videos, other)	Binary	

Source: author, 2022.

3.4. Data collection method

The method of data collection was through a questionnaire applied physically, due to the nature of the topic and to ensure representativeness of the data. Including those who are outside the digital world was one of the main objectives of the questionnaire and applying it using paper and pens was the way to ensure this.

The Carnisse population was approached face-to-face and was asked to collaborate in filling out a self-reporting form, where the user selects the boxes that best fit the answers. It has eight sections that measure the distinct levels of the digital divide and also obtain other information such as demographic and social inclusion characteristics. This form was generated with the group of students working on the CDO project on the digital divide in Rotterdam. The strategy with which the questionnaire was generated is following the levels of the digital divide proposed by Van Dijk's model, refer to the questionnaire in the annex 1. This measures first material access, i.e. access to the internet and access to digital devices, second motivational access, i.e. if they feel the need for inclusion in the digital world, third access to digital skills where skills with devices, software, and others are measured increasingly, and fourth an access to use where it is intended to measure the frequency of use of the internet and devices. Finally, the questionnaire includes general section which covers general demographic information such as age, gender, language, and nationality, among others.

This data collection was done in public places, community meeting centers, stores, and door-to-door within the neighborhood area. Figure 3 shows a map of the locations most frequently used to collect the responses. Among these places, the ones that stand out are KOCO Rotterdam

Foundation, a community meeting center with the objective of helping residents of Carnisse with housing, well-being, inclusiveness, and mental health, and the Amelandseplein park as a center for community social interaction and place where it was possible to collect several questionnaires of very varied profiles due to the high user traffic.

Figure 3. Map of data collection sites in Carnisse.

Source: author, 2022.

3.5. Data Analysis Techniques

The analysis of the collected data was done using mainly regression analysis, but also using summary statistics to describe the data and some characteristics about the residents of Carnisse. The measurement of the digital divide, as discussed in the literature review, presents several limitations; however, the creation of compound variables for each level of the ADT model and the creation of an Index was the way to score and define the digital divide in Carnise. The weighting of each sub-variable in the creation of the compound variable is based on the summary statistical analysis, and the weight for the index is based on existing similar indices measuring the topic.

3.5.1. Creation of the Compound Variables.

For the regression analysis, the dependent variables are Motivational Access, Material Access, Skills Access, and Usage Access. The creation of each, knowing that according to the operationalization there are several sub-variables measuring each level, was done using the percentage of responses, the importance of the sub-variables, and statistical models of acceptance tests based on internal consistency of the average covariance of the sub-variables (Alpha Test). For the Alpha test, the general rule is that coefficients between 0.6 and 0.7 imply an acceptable level of reliability, those 0.8 or higher imply a very good level of reliability, but coefficients higher than 0.95 imply redundance (Ursachi, Horodnic, & Zait, 2015). The creation of compound measures allows measurement of a relatively complex concept, however the

criticism of this type of variables rests on the oversimplification of complex interrelations by reducing the DD to a simple number; still, these indicators can work as openers outside of the scientific community (Vehovar, Sicheri, Husing, & Dolnicar, 2007) as is the case of this research, which aims to generate recommendations for policymaking. The following explains how each variable was created.

a. Motivation Access

The variables to be mixed for the compound of Motivational Access are stress, improve, and knowledge. According to the alpha test, the variable stress that measures the *Stress* of people of Carnisse when using digital devices has a weak correlation with *Improve* and *Knowledge* that measure the improvement in life due to digital devices and an improvement in general knowledge due to the use of digital devices. The coefficient of the Test scale of 0.1869 when combining all the variables suggests a weak correlation between the variables, but the test also shows the possible coefficient of 0.8945 when deleting the variable *Stress*, meaning a positive strong correlation. For the creation of the compound variable, equal distribution of weights are applied meaning both *improve*, and *knowledge* have a weight of 50%. The scales of both variables match the grading system defined for the questionnaire on the scale of 1 to 5, this implies a value of 0% if the user didn't report a value for the question, a 20% if they selected 1, 40% if selected 2, 60% if selected 3, 80% if selected 4 and 100% if selected the maximum value of 5. Values of "Non-applicable" and "I don't know" are considered as 0, not adding value to the measurement of the compound variable.

Table 2. Creation of variable Motivation Access.

Variable	Sub-Variables	weight
Motivation Access	Improve life (skmo_improve)	50%
	more knowledge (skmo_knowledge)	50%

Source: author, 2022.

b. Material Access

For the compound variable of Material Access, among all the sub-variables of this level, only four were used to create the compound. Those used are: *Computer* (a new variable created to represent desktops and laptops), *Smartphone*, *Tablet* and *Access to internet* (general). Although, the Alpha test was not tested among the variables of the level due to the unstandardized scale of the items, a coefficient of 0.6602 of the scale reliability was tested which indicates an acceptable level of reliability. The selection of the four variables of the compound variable was made considering the summary statistics and the importance of the responses. On the other hand, Table 3 shows the percentual weight for the sub-variables used; 80% was selected for computer and access to internet due to the high rates of response and their importance, considering the fact that other methodologies such as DESI or NRI for digital devices consider only computers, not tablets or smartphones, and the fact that access to internet in general is more representative than access to internet in work or while traveling. Smartphone, even though it has a very high percentage of positive responses, is not considered a determinant variable to measure the digital divide. The number of devices was not considered in the creation of these compound due to the low rates of response, similarly with the access to internet while

traveling or at work, that had no influence in the access of internet in general.

Table 3. Creation of variable Material Access.

Variable	Sub-Variables	weight
Material Skills	Computer	80%
	Access to internet	
	Smartphone	20%
	Tablet	

Source: author, 2022.

c. Skills Access

The Skills Access compound variable was created using the five subsections and each variable within the subsection. The Alpha tests for each section showed coefficients of 0.8653 for Operational Skills, 0.7800 for Info Seeking Skills, 0.9491 for Software and Content Creation skills, 0.6863 for Safety and Security, and 0.8978 for Problem Solving skills, indicating 'acceptable' to 'very good' levels of reliability, but not high enough to imply redundance according to the accepted limits. For this reason, none of the sub-variables were omitted. The weights of each subsection are based on the number of sub-variables each subsection has, as shown in Table 4. It is important to clarify that the reason this compound variable was created in this way is because more in-depth analysis was done in terms of the skills to explain the effect of the main demographic factors, since according to simple models, some of them were not significant. Additionally, it should be noted that Operational Skills is a binary section, with yes or no responses to skill statements, compared to the rest that are on a scale of 1 to 5 rating of ability.

Table 4. Creation of variable Skills Access.

Variable	Sub-Variables	Indicators	weight
Skills Access	Operational skills	op_wifi	32%
		op_info	
		op_apps	
		op_files	
		op_attach	
		op_forms	
		op_virus	
	Info seeking skills	skif_keywords	9%
		skif_navigate	
	Software and content creation skills	skcc_settings	36%
		skcc_apps	
		skcc_word	
		skcc_excel	
		skcc_formulas	
		skcc_presentations	
		skcc_media	
		skcc_software	
	Safety and Security skills	skss_trust	14%
		skss_share	

		skss_safesharing	
	Problem solving skills	skps_problems	9%
		skps_support	

Source: author, 2022.

d. Usage Access

For the last level, Usage Access, four variables were considered. Email is a binary variable based on a yes or no response; frequency of usage of internet is on a scale from 1 to 6, with 1 never and 6 daily; frequency of usage of apps or programs with the same scale, and the purpose of usage with 12 options of multiple selection. The Alpha test for this compound variable shows a coefficient of 0.7549 meaning a strong positive correlation and acceptable level of reliability, making the variables combinable. The percentages were assigned equally, nevertheless, each sub-variable has a different percentage based on question type. Email has two possibilities 0 or 1 with 1 being 25%, frequency of use of internet and apps with values of 20% for each option of the scale where daily is 100% of the question, and finally, purpose of use with each option having a value of 1/12. The following table shows the weights of each sub-variable in the creation of the compound.

Table 5. Creation of variable Usage Access.

Variable	Sub-Variables	weight
Usage access	email	25%
	Frequency of internet use	25%
	Frequency of Apps Use	25%
	Purpose of use	25%

Source: author, 2022.

3.5.2. Creation of the Digital Divide Index.

The creation of the Digital Divide Index follows the same logic as the creation of the previous compound variables for the four dimensions of the ADT model; it combines each dimension into one index. The distribution of weights of each level was equally distributed assigning 25% to each level, following the reasoning of the methodology of creation of DESI (DESI, Methodological note, 2021, p. 12) and NRI (World Economic Forum, 2021, p. 257), as comparable indices measuring the topic.

Even though the Netherlands is considered a country with high level of Material Access, the variable is considered at the same level as the others to respect the methodology. Further discussion on the weight of variables is mentioned in Chapter 5. The following table reflects the equal weights of each dimension in the creation of the index. Analysis of the index was used to score the neighborhood in terms of the inclusion of its residents in the digital environment. Also, for further application of the research to the rest of the city, the index represents a way to quantify with a general number the neighborhood and to compare with other areas.

Table 6. Creation of Digital Divide Index.

Variable	Sub-Variables	weight
Digital Divide	Material Access	25%
	Motivation Access	25%
	Skills Access	25%
	Usage Access	25%

Source: author, 2022.

3.5.3. Hypotheses testing methodology.

Finally, to test the hypothesis presented in Section 1.2, the significance and direction of effect (positive or negative) of the demographic factors in the regressions on each one of the levels was analyzed. The factors that show no significance are considered as a rejection of the hypothesis. The values of the Adjusted R^2 for each of the regressions are also considered as an additional way to test the hypothesis; higher levels of explanatory power reflect more credibility of the models resulting in more criteria for accepting or rejecting the hypothesis.

3.6. Validity and Reliability: description and limitations

It is important to also explain the validity and reliability of the study, considering that one measures the certainty in the application of the methodology and the other the precision and consistency of the measures. It is necessary to understand that this is exploratory quantitative research, so it is hard to measure the validity of a study like this one, considering the lack of similar information about Rotterdam. For this reason, the internal validity is considered moderate due to the lack of information, but because of the applied methodology for data collection and the analysis techniques, and due to the triangulation of information with the available literature, studies on a country level, and European digitalization indices, the gap in validity is addressed. On the other hand, the external validity is considered to be moderate since the results cannot be generalized beyond Carnisse; the findings describe the neighborhood not the general status-quo of the city. Nevertheless, the methodology of data collection, measurement, and analysis compensated for this gap because it can be easily extrapolated to other neighborhoods or can be applied on a larger scale.

Moreover, regarding the reliability of the study, econometric models and data sets have limitations. However, this research is considered to have an elevated level of reliability, since the operationalization of the concepts followed by the creation of the questionnaire ensures an accurate measurement of the DD. Additionally, the questionnaire was translated into four languages to have a better understanding of the users who responded.

As explained above, the sample had to be randomly selected in a range of ages over 18 years old, to guarantee the basic assumptions of the analytical methodology. In addition to this, the data was cleaned so that incomplete questionnaires or questionnaires with confusing information were eliminated in order not to alter the data, and finally, the sample collected is larger than the one needed in order to guarantee reliability through the robustness of the information.

Chapter 4: Results and analysis

4.1. Data description

The data collected in the fieldwork consists of a database of 187 observations, randomly collected in the neighborhood of Carnisse. The responses obtained are remarkably diverse, however, they are linked because they were obtained in urban areas, community meeting centers, parks, stores, restaurants, and homes in the neighborhood. This data provided the first introduction to the complexity of the topic due to the diversity of the sample, however, it has helped assess the validity of concepts explained before, such as superdiversity or high material accessibility, which will be detailed later in this chapter.

The data for this research satisfied sufficiently the expectations; the number of observations is higher than the calculated allowing more robust results. The individuals observed are between 18 years old and 99 years old, a spread distribution in terms of age. The same is true of factors such as education, income, employment, and languages that the range of responses covers all the categorical possibilities of the questions, guaranteeing a spread distribution. Table 7 shows the summary statistics of the demographic factors, which help describe the data.

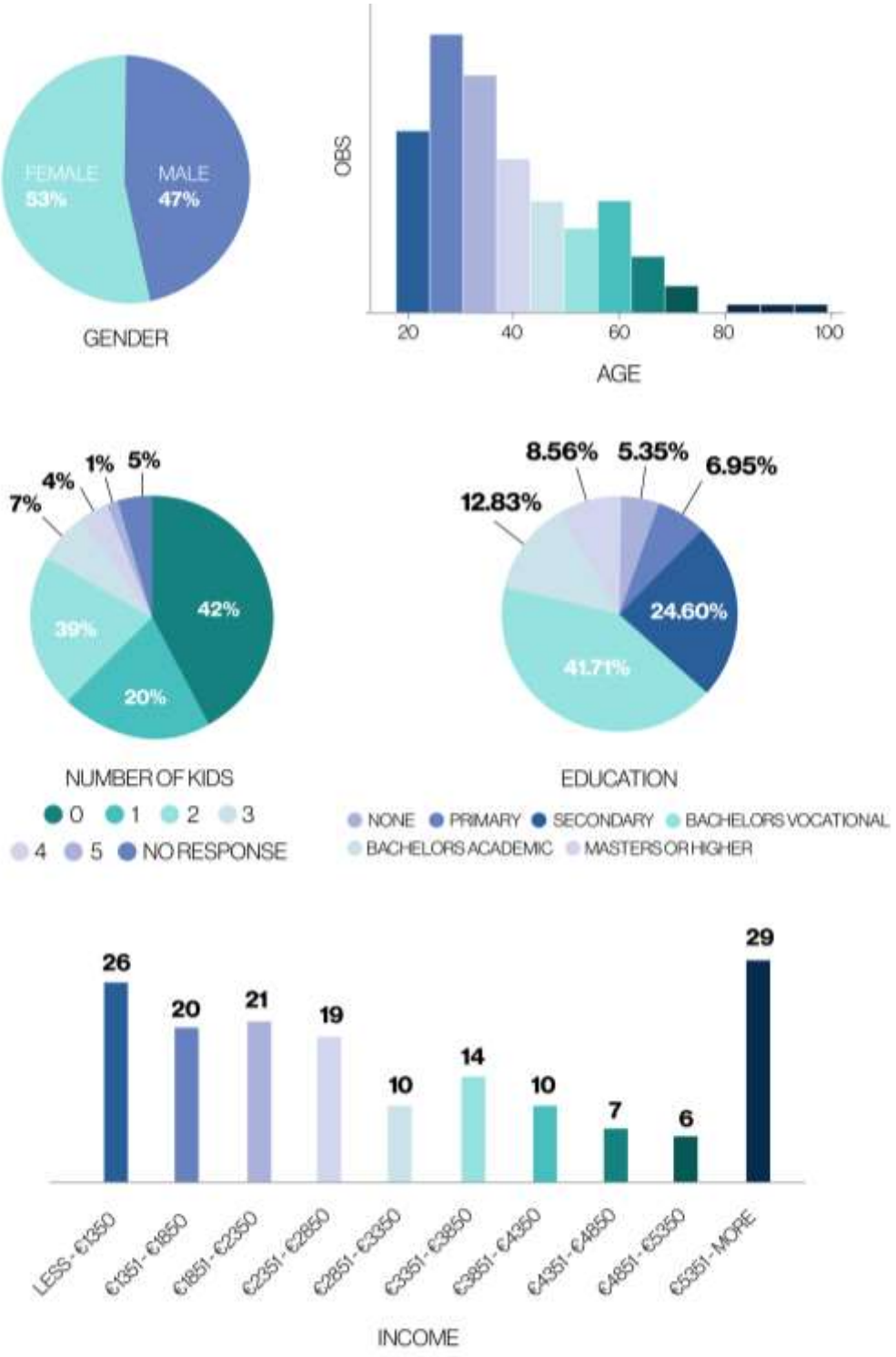
Table 7. Summary Statistics of Demographic factor.

Variable	Obs	Mean	Std. Dev.	Min	Max
Age	181	38.873	15.021	18	99
Gender	187	.535	.5	0	1
Education	177	2.91	1.024	1	5
Nationality	177	15.028	4.113	1	24
Income	162	4.994	3.189	1	10
Kids	178	1.09	1.232	0	5
Employment	146	2.5	1.895	1	7
Dutch	142	3.225	1.157	1	4
English	149	2.711	1.002	1	4
Email	182	.951	.217	0	1

Source: author, 2022.

Furthermore, the graph 1 presents an overall analysis of the main factors further showing the diversity of the responses. As seen, the average age is 38.87 and there is a large concentration of the population between 20 and 40 years old; this result is obtained in spite of having some outliers between 80 and 100 years of age. The gender is equally distributed, but with 3% more females (53%) than males (47%). The number of kids is from 0 to 5 kids, this result is attributable to the nature of the question because it asks only for children under 18 living with their parents, the results show a 42% of the sample with no children at all or no children under 18 living with them, 20% with 1 child, and 39% with 2 children. For the level of education 41.71% of respondents present a bachelor's degree in a vocational profession (HBO, MBO), and only 8.56% with a master's degree or higher, resulting on an educated population but not highly educated. It is important to mention that only a low rate of 5.35%, i.e., 10 responses showed no education at all or no response considering the characteristics of Carnisse mentioned in the previous sections. Similarly, the salary (income) presents different answers, but it is interesting to mention that the highest concentration of answers is between "less than 1350 euros" and "more than 5350 euros" unmasking a salary gap in the area. With this first analysis, it can be assumed that the majority of the population is young professionals (20 to 40 years old) with at least a secondary title.

Graph 1. Demographic Factors

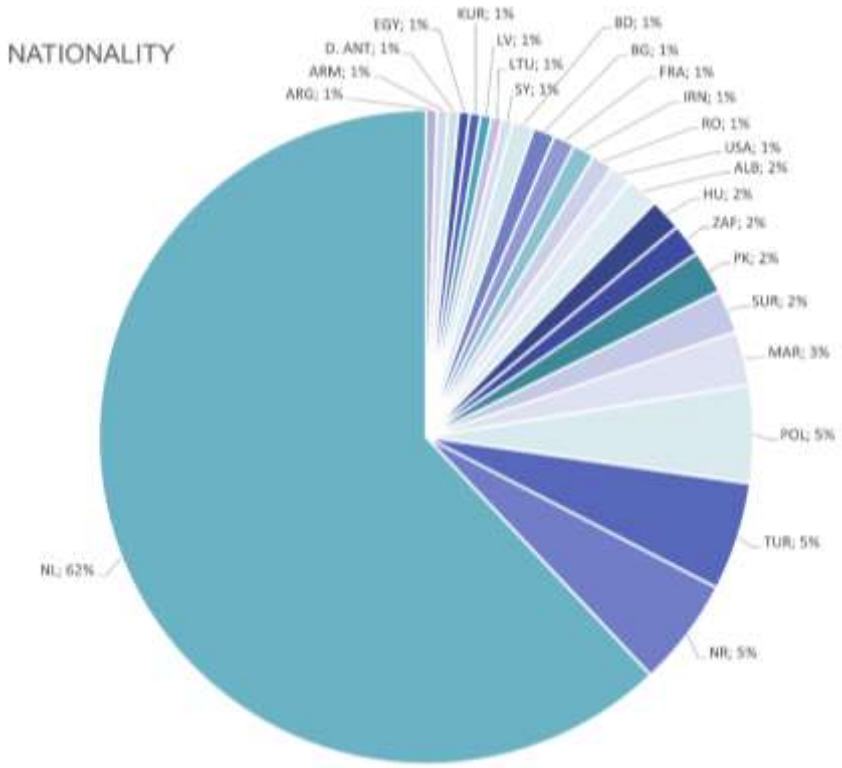


Source: author, 2022.

Regarding the ethnicity, the range of the variable is from 1 to 24, meaning that among the 187 observations, there are 23 nationalities plus a non-response category, confirming the superdiversity of the city and a superdiversity within the neighborhood. The graph 2 shows the distribution of nationalities among the sample; Dutch is 62% of the population with 116 observations, the next highest are Polish and Turkish at 5%, and with the same percentage of 5% is non-response. The rest of the nationalities varies from 1% to 3%, meaning one to two responses from an individual from the country. Even though with this statistic it is possible to

confirm the concept of superdiversity, it is not possible to cluster the digital divide in terms of the nationality; the low response of some nationalities made the topic difficult to study in detail. On the contrary, the Dutch nationality with 116 responses made a representative sample for the Dutch community in the neighborhood. Further analysis clustering the nationalities by continents or EU countries and non-EU countries could be done, but is out of the scope of this research because it will not have a strong representativeness of the populations.

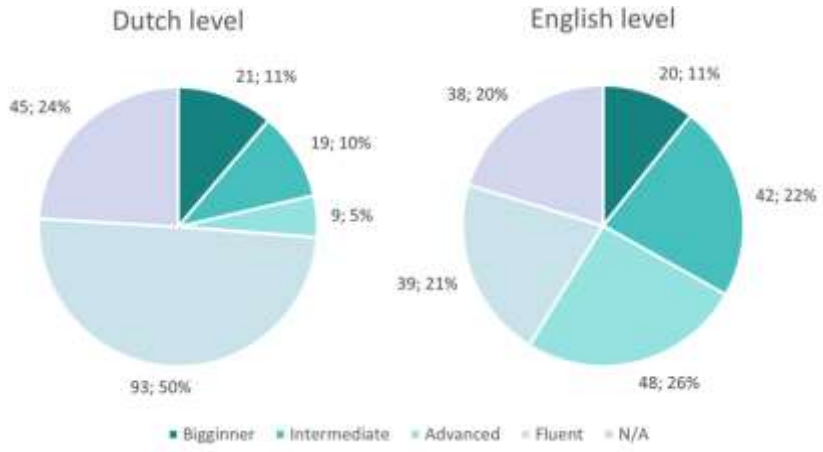
Graph 2. Nationality



Source: author, 2022.

Finally, concerning the language of the sample there are a total of 37 languages for native languages, meaning that also is not possible to cluster the results due to the low responses for each language. Regarding, the level of Dutch and level of English, the graph 3 shows the distribution of both. For Dutch, an exact 50% of the observations has a fluent level and 24% is non-applicable, which could be native speakers or non-responses. It is similar with English where around 80% of the sample knows the language at least on a beginner level (N/A could also be native speakers, meaning the percentage might be higher), 21% of Fluent English and 26% of Advanced levels. This also shows the diversity of the city with English serving as a lingua franca in the country.

Graph 3. Language



Source: author, 2022.

4.2. Summary statistics Digital Divide Levels

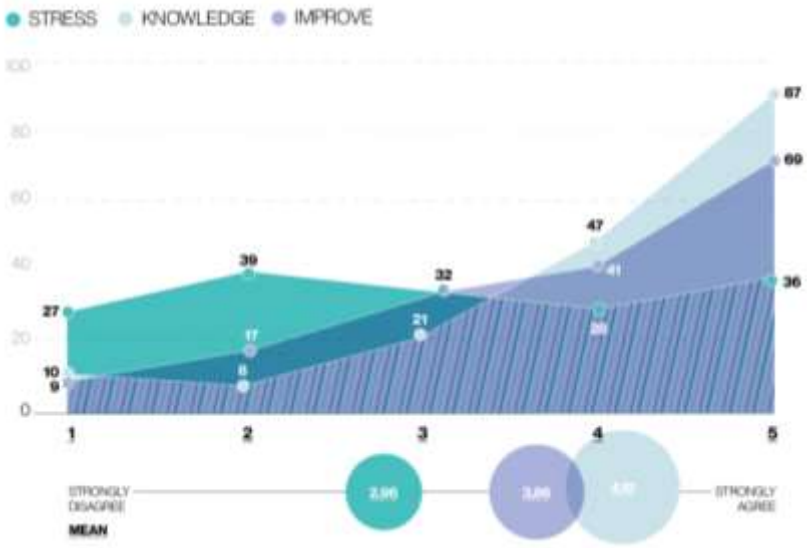
With the summary statistics mentioned above, a general idea of the population of the people of Carnisse is created. However, is not possible to conceive any digital exclusion by only considering the demographic factors. As was mentioned in the theory review, these factors are the ones that describe the DD, but knowing specific characteristics of digitalization allows a clearer picture of the topic. The following is an analysis of the basic statistics in each of the levels of the ADT model for the Carnisse respondents. The purpose of this section is to further describe the data before determining which demographic and social factors describe each level of accessibility.

4.3.1. Motivation Access

The first level to be analyzed is Motivation Access, measured by three variables: stress when facing a digital world (Stress), improvement in daily life thanks to the use of technologies (Improve), and the development of knowledge through digital technologies (Knowledge). These variables were evaluated on a scale of 1 to 5, where 1 was strongly disagree and 5 strongly agree in terms of the assertiveness of the response. The results as seen in graph No. 4, reveals a mean of 2.96 for Stress, 3.86 for improvement, and 4.12 for Knowledge, showing that motivation is not high, however, it is still above the 50-percentile, demonstrating a progress of the people of Carnisse. The function of Stress appears to be more constant meaning a spread distribution of the responses, which is why the mean is low; however, it is different for Improve and Knowledge which show an increasing behavior and high responses in 5 (strongly agree).

To better understand this measurement, it is necessary to understand the variables along with other factors, when relating the variables with Education it can be seen that common level of education in the sample is a University Bachelor's degree meaning that Knowledge and Improve even though were directly ask in terms of digital devices is proportionally related to the education. 87 responses of Knowledge were 5 (strongly agree), a total of 50,28% of the sample agree on the fact that having access to internet and digital devices has increased their knowledge, equivalent percentage of highly educated people among the sample (Bachelor's and master's degree).

Graph 4- Motivational access: stres, Knowledge, Improve



Source: author, 2022.

4.3.2. Material Access

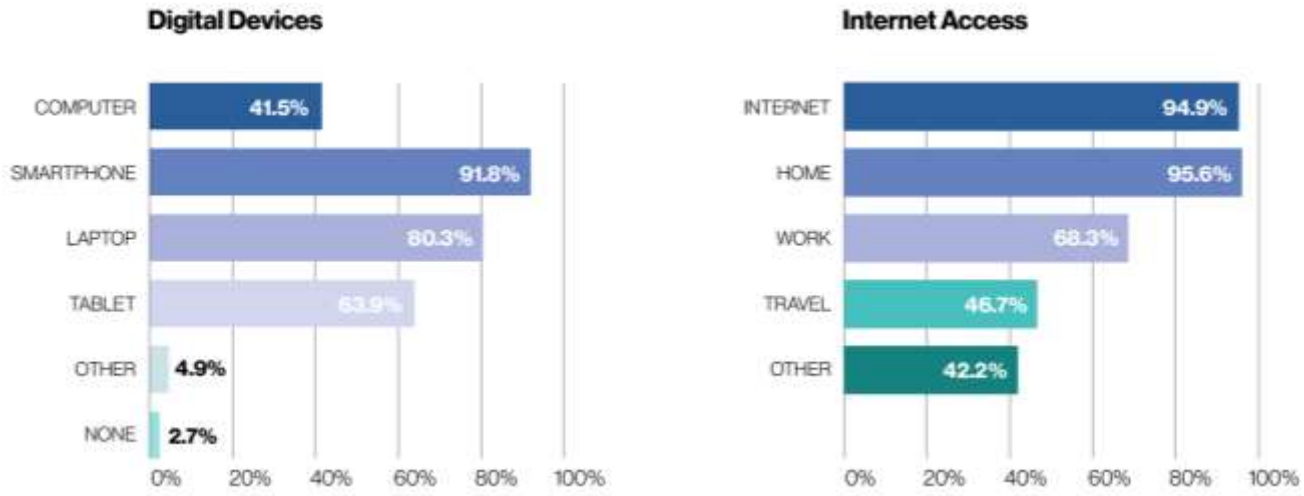
Regarding the second level, Material Access, where, as reviewed in the theory, this level consists not only of internet access, but also access to digital devices. Specifically for the population of the area, the survey was used to collect data on access to four types of digital devices and internet access in different spaces. The digital devices are desktops, laptops, smartphones, tablets, and other, or none of them. As can be seen in graph No. 5 the entire sample has high values of accessibility, with access to a smartphone being the highest at 91.8%, followed by access to a laptop with 80.33% of the population. Tablet and Desktop have lower values, however, they can be considered as dispensable for digital inclusion since the same can be done with the other two (smartphone or laptop). As for people who have access to another device, it is a small percentage with only 4.92% and they were devices such as electronic books or video game consoles, a negligible result for the purposes of this study. Moreover, considering the percentage of the population that does not have access to any device, it is almost insignificant with a value of 2.73%, which means that in the opposite sense, 97.27% of the population has access to at least one device or a mixture of those mentioned above.

With respect to internet access, it was measured in different places such as home, at work, while traveling, or some other place. The results as can be seen in the same graph shows that the overall internet access is 94.94% and is comparable to the value of access at home with 95.56%, we can assume that access at work, while traveling or some other is insignificant to measure the digital divide since access at home is considered the more important characteristic. These comparable percentages of access to internet in general and access at home confirm those observed by the NRI index which mentions that Netherlands have a high rate of digitalization with more than 80% of connectivity and access to 5G connections (World Economic Forum, 2021), referring to this as the development of ICTs ergo internet access.

Between these two measures that characterize the level of material access, it can be observed that the district of Charlois and more specifically the Carnisse neighborhood is not excluded at this level and the percentage of digital segregation is low. The specific percentage is mentioned in the next section with the creation of the compound variables of each level. When referring to material access, a more in-depth analysis is needed to determine why there is still a 2,73%

measure of non-accessibility to devices, since the chances of having at least one device are remarkably high. This is also the case considering the 5.06% of population without accessibility to internet.

Graph 5. Material access; digital devices, and internet access of Carnisse



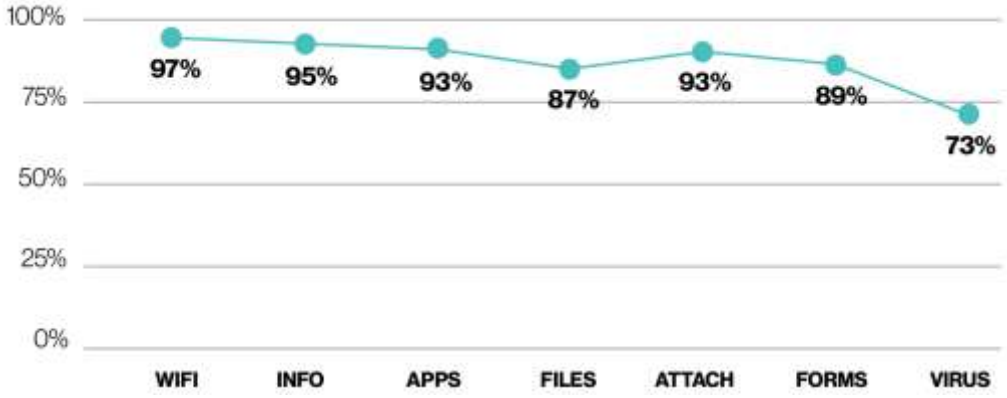
Source: author, 2022.

4.3.3. Skills Access

Next, the Skills Access level was measured by dividing the skills into five sections that evaluate the operational skills, information seeking skills, software and content creation skills, safety and security skills, and problem-solving skills. These sections were quantified in the same way with sub variables on a scale from 1 to 5 with 5 being the maximum value, except for the operational skills which were measured through Yes or No questions.

Starting with operational skills, this is composed of seven sub-variables that measure whether the user knows how to connect to Wi-Fi (Wi-Fi), how to search for information using a search engine (Info), how to install applications or programs (Apps), how to download and save documents (Files), how to attach documents to an email (Attach), how to complete online forms (Forms), and how to avoid viruses on the device (Virus). As can be seen in graph No. 6 the responses of the skills are decreasing as the complexity increases. Starting with a 95% of positive responses on Wi-Fi and ending with a 73% on Viruses demonstrates that the Carnisse population has an important level of development in terms of operational variables, but not technical or higher IT skills due to the decrease when increasing the difficulty.

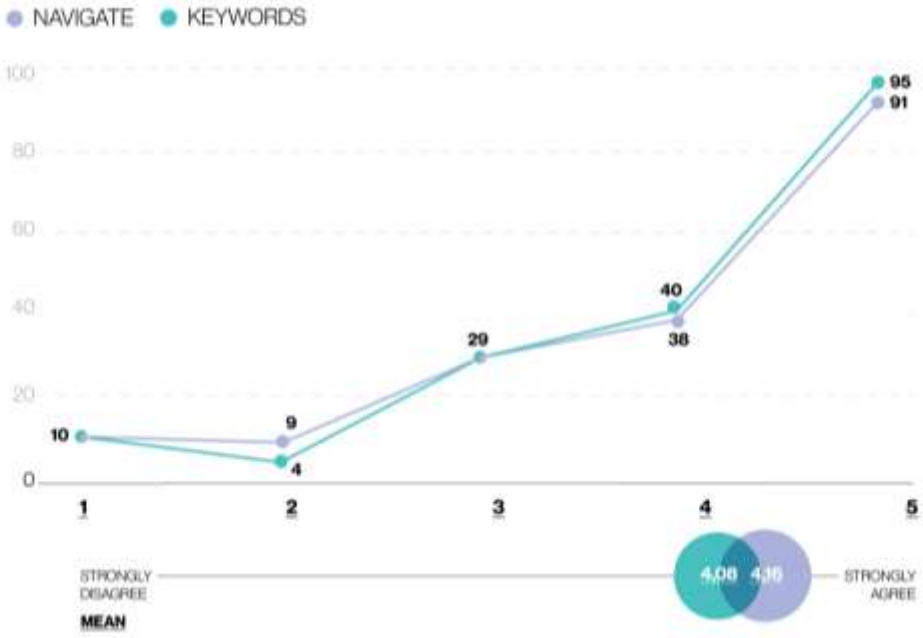
Graph 6. Skills Access: operational skills



Source: author, 2022.

With regard to the information seeking skills, this variable was measured taking into consideration two sub-variables also measured with a 1 to 5 scale, where 1 is not true at all and 5 is very true. The first sub-variable was the ability of knowing and deciding the best keywords to use in online searches (Keywords) and the second one the facility to use or navigate in most websites (Navigate). The following graph shows the means among all the observations, with values of 4.08 for keywords and 4.16 for Navigate. Also, in the graph it can be seen the distribution of the answers where a high selection at value 5 equivalent to "very true" is appreciated in both variables. These values show a high development in terms of this skill.

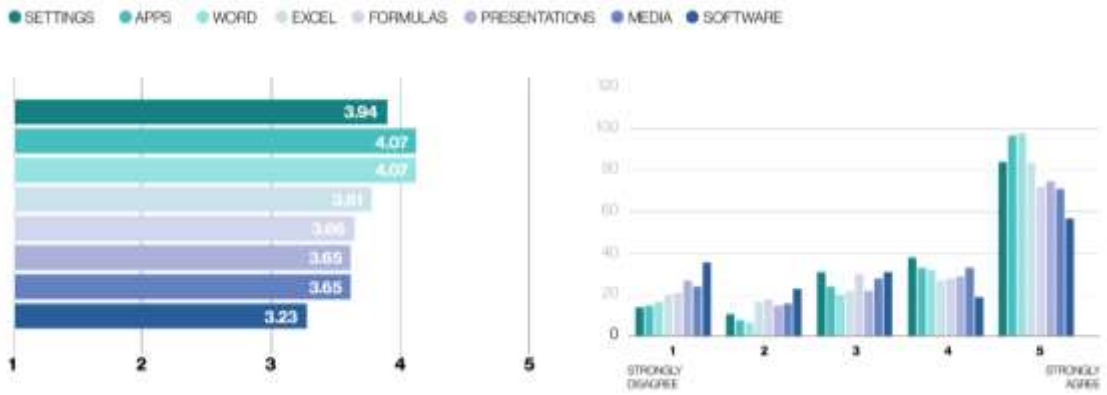
Graph 7. Skills Access: information seeking skills



Source: author, 2022.

Similarly, with the variable of software and content creation, it is composed of eight sub-variables that measure the ability to adjust settings (Settings), the ability to configure and install new programs (Apps), the ability to produce and edit content in Word (Word), the ability to produce and edit content in Excel (Excel), the ability to use formulas using spreadsheets (Formulas), the ability to produce presentations (Presentations), the ability to create media (Media), and the ability to use specific advanced software such as AutoCAD, Revit, Photoshop, etc. (Software). It can be observed in graph 8 that these skills, like the operational skills, start high and decrease according to the degree of complexity until the last one, Software, which shows an average value of 3.23. Still, with the lowest value of 3.23 for Software being above the median of the scale, this demonstrates a high development of the population. On the other hand, the right side of the graph shows the distribution of the responses and displays a similar increasing behavior for each sub-variable. It is important to note that for Software the selection of 1 "not very true at all" is higher than the responses of 2, 3, or 4, reflecting the complexity of the variable with a more constant distribution between the answer choices.

Graph 8. Skills Access; Software and content creation



Source: author, 2022.

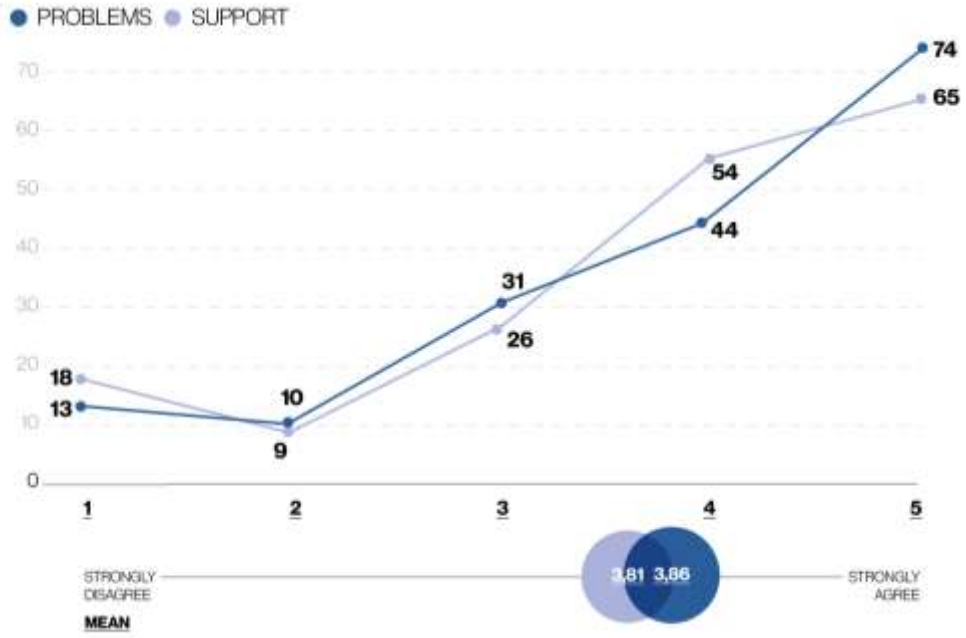
For Safety and Security skills, three sub-variables were measured: the trust of information and websites online (Trust), the ability of knowing which information should be shared online (Share), and the feeling of safety when sharing personal information for services (Safesharing). As seen in the graph 9. The means are 3.80 for trust, 4.27 for share, and 3.39 for safesharing. A similar behavior is seen as before with Information seeking skills and software and content creation skills. There is a high score for Share and medium-high for the other two variables. With the high mean of 4.27 for Share, it could be demonstrating that the people of Carnisse feel confident in terms of the content they are looking for.

Graph 9. Skills Access; Safety, and security skills

Source: author, 2022.

Concerning the Problem Solving skills, two sub-variables were quantified. The first one is the personal ability to solve routine problems with the devices such as close programs, restart computer, reinstall/update programs or check internet conecction (Problems), and the personal ability to find support and assitance when a technical problem occurs (Support). In graph 10, the results are a mean of 3.86 for Problems and 3.81 for Support, very comparable results between each other and also when considering the distribution of the responses. The behaviour with these variables is same as the rest of the skills variables, showing an increase of responses on the value of 5 meaning high skills according to the scale.

Graph 10. Skills Access; Problem solving

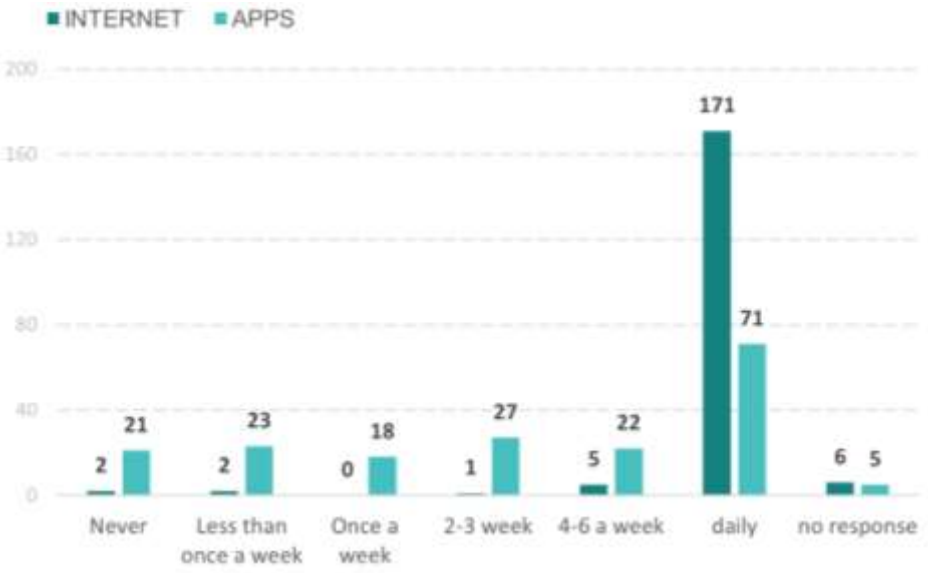


Source: author, 2022.

4.3.4. Usage Access

For the last level of the ADT model the Usage Access, there are three sub-variables which are the frequency of internet use, the frequency of use of software or applications, and then the purpose of use for which the option to select among twelve options was given. As can be seen in graph 11 internet use is mostly daily with very few responses for other frequencies, the reasons for which will be analyzed in the next section. As for the frequency of use of applications or software, a more normalized distribution is observed; however, daily was the most common selection with 71 responses among the 187 observations.

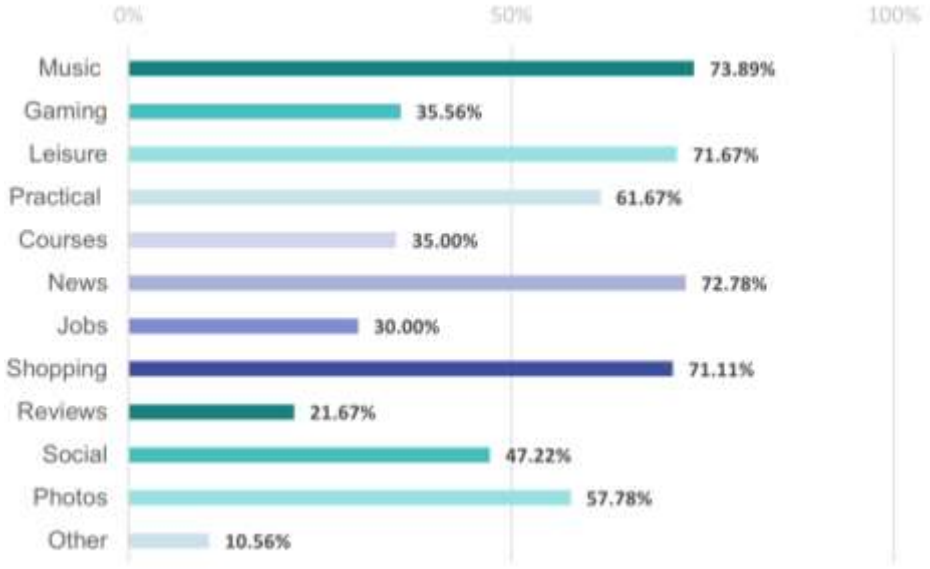
Graph 11. Usage Access; Frequency of use



Source: author, 2022.

On the other hand, about the purpose of use, graph 12 shows the 12 options. The answers to each option could be any. High percentages were observed with more than 70% for listening to music, pleasure, news, and shopping. And low percentage can be observed for Gaming, Courses, Jobs, reviews and Social. With these results is difficult to conclude anything about the usage access, more in-analysis is needed, however, more positive uses for career development or education (Jobs and Courses) area lacking in the area.

Graph 12. Usage Access; Purpose of internet use



Source: author, 2022.

4.3. Description of compound variables and Digital Divide Index

4.3.5. Compound Variables

After independently analyzing each of the variables of the levels of ADT, composite variables were created to form the Digital Divide index with which Carnisse's digital exclusion was measured. The creation of the variables with the explanation of the weights given to each sub-variable was explained in Section 3.5. The following table 8, shows the statistical summary of the four composite variables on a scale from 0 to 1, where each of the variables is represented as a percentage.

When analyzing the mean, a general development in each of the levels can be observed. In terms of material access, there is an outstanding development with 88.4%, meaning that acquiring an electronic device or access to the Internet is not a problem for most of the people in the neighborhood. The other three levels, although lower, also show an important level of development with values above 70%. Motivation, with a value of 72.5%, is the lowest of the four levels. The reasons and factors that led to this result are analyzed below.

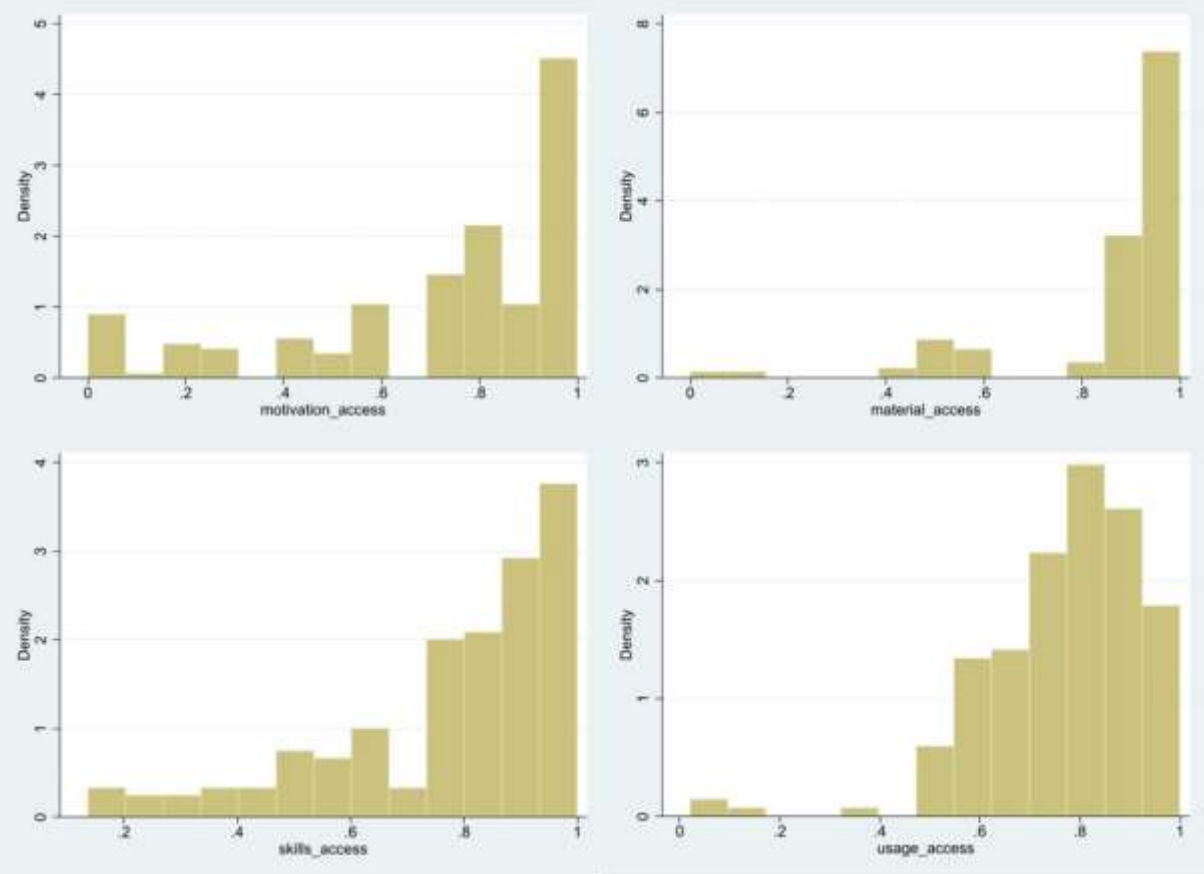
Table 8. Summary Statistics of compound variables

Variable	Obs	Mean	Std. Dev.	Min	Max
material access	178	.884	.204	0	1
motivation access	187	.727	.303	0	1
usage access	178	.769	.158	0.028	1
skills access	180	.775	.212	0.136	1

Source: author, 2022.

Regarding the distribution of the observations of the compound variables, graph 13 shows a histogram of each compound. The four variables present a normal distribution with more concentration between 0,7 and 1, explaining the percentages of the means. Although there are some outliers, the distributions demonstrate a wide range of results and the performance of Carnisse in terms of these levels. With these results, it is clear that even though it is not as marked as other characteristics of the city, there is still segregation in the neighborhood, it is minimal but not negligible. Knowing that the DD is due to demographic factors, the regression analysis will determine why and to what extent the population of Carnisse is exposed to the presented gap. As explained before, the first hypothesis was rejected due to the low representativeness of each nationality, although the superdiversity was confirmed. The other hypotheses considering age, education, and income with these results seem to be aligned, but it is not enough information to test them.

Graph 13. Histograms of compound variables



Source: author, 2022.

In addition to the distribution of the data, table 9 shows the correlations between the compound variables and the regressors of demographic characteristics. The correlations tend to be low, except for Age and Skills Access, Education and Skills or Usage Access, and English and Skills or Usage Access, that presents coefficients with moderate correlation. Only the correlations within the levels present moderate high correlations with coefficients of 0.603 between Motivation and Skills Access, and 0.665 between Skills and Usage Access, this could be attributed to the linearity of the model where to reach one level, the one before needs to be surpassed, without implying causality. This supposed linearity of the model will be discussed in Chapter 5. Moreover, with these results of low to moderate correlation it is assumed that there is not multicollinearity between the variables, making the analysis a reliable methodology to test the phenomenon.

On the other hand, a first insight of which factors would be determinants in each level can be concluded from this table: Age in Skills Access, Education in Skills and Usage Access, and English in Skills and Usage Access all at a 99% confidence level.

Table 9. Correlations of compound variables and demographic factors

Pairwise correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
(1) motivation_access	1.000												
(2) material_access	0.376***	1.000											
(3) usage_access	0.445***	0.470***	1.000										
(4) skills_access	0.603***	0.434***	0.665***	1.000									
(5) Age	-0.220***	-0.178**	-0.168**	-0.459***	1.000								
(6) female	0.042	0.017	0.011	-0.036	-0.025	1.000							
(7) educ	0.239***	0.335***	0.453***	0.444***	-0.196***	-0.022	1.000						
(8) income	-0.008	0.286***	0.259***	0.244***	-0.020	-0.212***	0.275***	1.000					
(9) nationality	-0.048	-0.177**	-0.161**	-0.105	0.229***	-0.126*	-0.203***	-0.020	1.000				
(10) Dutch	0.013	0.181**	0.138*	0.144*	0.173**	0.145*	-0.101	0.124	0.026	1.000			
(11) English	0.289***	0.209**	0.486***	0.472***	-0.322***	-0.037	0.387***	0.220**	-0.295***	-0.004	1.000		
(12) kids	-0.107	-0.010	-0.074	-0.015	-0.119	-0.008	-0.121	0.037	0.041	-0.034	-0.169**	1.000	
(13) employment	-0.034	-0.284***	-0.229***	-0.294***	0.327***	0.275***	-0.293***	-0.427***	0.116	-0.127	-0.148*	-0.104	1.000

*** p<0.01, ** p<0.05, * p<0.1

Source: author, 2022.

4.3.6. Digital Divide Index

After the analysis of each level, the Digital Divide Index aims to reflect an overall behavior of the population of Carnisse in terms of digital inclusion. It is important to mention that this index considered the four levels and create an average result to score Carnisse, but to better understand digital exclusion, the analysis of the prior models is clearer and more detailed.

Starting with the summary statistics of the index in table 10, a mean of 79.9% shows a high score which matches the country-level scores in the other considered indexes. The score of the index of Carnisse is comparable with the 82.06% in the RNI index obtained by the Netherlands in 2021 (World Economic Forum, 2021, p. 29). Also, it matches exactly the score of 79.9% in Digital Public Services of the DESI index of 2021 (DESI NL, 2021, p. 13), although the value in this pillar increased to 84.2% for the 2022 (DESI NL, 2022, p. 16) and it measures the digital public services for citizens and businesses, instead of the general digital inclusion. It shows a comparable result for the topic of digitalization, suggesting an accurate result of this index. Undoubtedly, the DESI index measures more than just digital public services, it also measures integration, connectivity, and human capital, but with a focus at a country level not individual. Therefore, the general score for the Netherlands in the DESI index is lower (67,4%) than the Digital Divide Index obtained in this research.

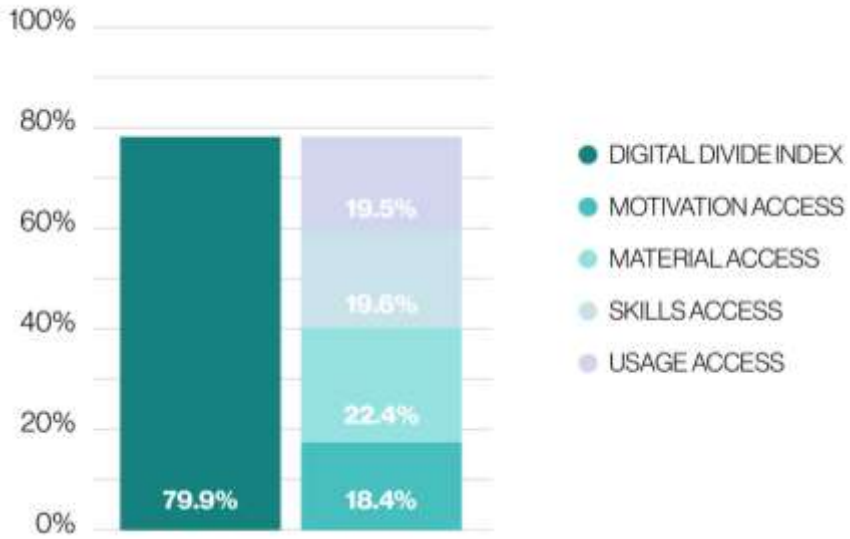
Table 10. Summary Statistics of Digital Divide Index

Variable	Orbs	Mean	Std. Dev.	Min	Max
digital divide	169	.799	.164	.064	.995

Source: author, 2022.

From the index mean, a high level of digitalization in Carnisse can be inferred, due to the values explained in the previous section where material access, with more than 97% inclusion, increases the overall Digital Divide Index average. The following graph summarize the scores of each sub-level within the Digital Divide Index.

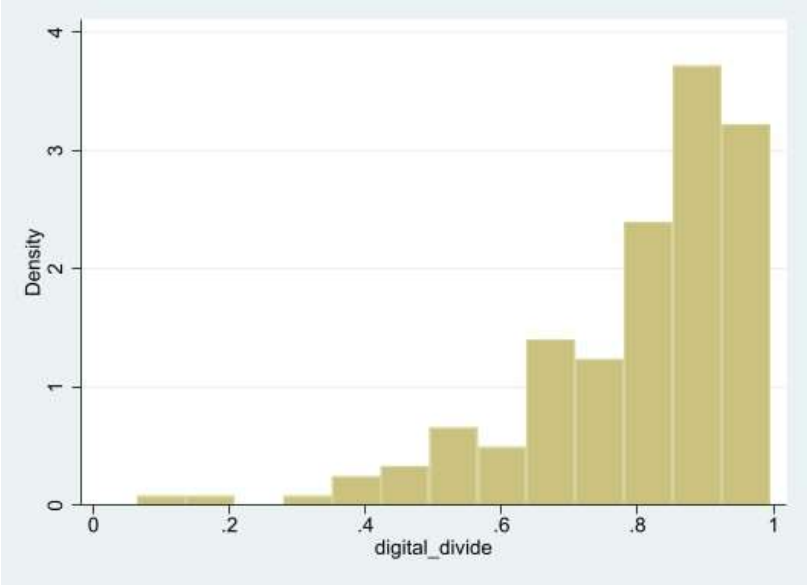
Graph 14. Digital Divide Index, Carnisse



Source: author, 2022.

In terms of the distribution of the data, the index presents a normal distribution with some outliers between 0 and 20%. The graph 15 shows how the concentrations are located actually between 80% and 100%, but due to the outliers the mean stays at 80%.

Graph 15. Distribution of Digital Divide



Source: author, 2022.

4.4. Analysis of the compound variables and Digital Index

To explain further the distributions and to determine which factors are defining and describing these behaviors in Carnisse, the tables display the results obtained from regression analysis, showing the significance and the coefficient of each demographic factor. Different models were run to prove the influence of each regressor. The following tables summarize the models that best fit each of the levels, taking into consideration the explanatory power of the model, the number of observations, the significance of the factors, and the non-linearity of the fitted lines. Each compound variable behaves differently, therefore not all the models are similar.

Table 11. Models of Motivational Access

	(1) lnmotivation	(2) lnmotivation	(3) lnmotivation	(4) motivation_access
age	-0.00710**	0.0236**	-0.0133***	-0.00369*
	(-2.57)	(2.20)	(-3.23)	(-1.66)
female	0.0482	0.0834	0.0916	-0.0218
	(0.62)	(1.10)	(1.14)	(-0.35)
educ	0.113***	0.0962**	0.0980**	0.0493
	(2.91)	(2.55)	(2.51)	(1.59)
income	0.0152	0.0122	-0.0438	-0.0740**
	(1.13)	(0.95)	(-1.35)	(-2.12)
nationality	0.00984	0.00963	0.0113	-0.00578
	(1.17)	(1.20)	(1.36)	(-0.54)
dutch	0.0652*	0.0549*	0.0542	0.0218
	(1.93)	(1.69)	(1.61)	(0.80)
english	0.116***	0.125***	0.121***	0.0898***
	(2.71)	(3.04)	(2.87)	(2.71)
kids	0.0217	-0.00282	0.0273	-0.00912
	(0.67)	(-0.09)	(0.86)	(-0.36)
employment	0.0559**	0.0652**	0.0613**	0.0177
	(2.18)	(2.63)	(2.42)	(0.85)
age2		-0.000315***		
		(-2.95)		
ageincome			0.00172**	
			(2.00)	
raceincome				0.00417*
				(1.84)
_cons	-1.286***	-1.868***	-1.076***	0.561**
	(-4.24)	(-5.32)	(-3.40)	(2.16)
N	95	95	95	101
R^2	0.340	0.402	0.370	0.233
adj. R^2	0.270	0.331	0.295	0.148

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$
Source: author, 2022.

Table 12. Models of Material Access

	(1) material_access	(2) material_access	(3) material_access	(4) material_access
age	-0.00142	0.0170***	-0.00420*	0.0155**
	(-0.96)	(2.96)	(-1.88)	(2.13)
female	0.0137	0.0335	0.0341	0.0370
	(0.33)	(0.83)	(0.79)	(0.89)
educ	0.0498**	0.0405**	0.0427**	0.0394*
	(2.42)	(2.06)	(2.05)	(1.97)
income	0.00741	0.00515	-0.0187	-0.000480
	(1.05)	(0.77)	(-1.08)	(-0.03)
nationality	0.00252	0.00244	0.00308	0.00257
	(0.57)	(0.58)	(0.70)	(0.60)
dutch	0.00420	-0.000842	-0.000964	-0.00173
	(0.23)	(-0.05)	(-0.05)	(-0.10)
english	0.0159	0.0232	0.0163	0.0229
	(0.70)	(1.07)	(0.72)	(1.05)
kids	0.0213	0.00888	0.0221	0.00967
	(1.26)	(0.54)	(1.32)	(0.58)
employment	-0.0194	-0.0129	-0.0174	-0.0127
	(-1.42)	(-0.98)	(-1.28)	(-0.97)
age2		-0.000188***		-0.000179***
		(-3.31)		(-2.83)
ageincome			0.000767	0.000169
			(1.65)	(0.34)
_cons	0.672***	0.307	0.775***	0.348
	(4.16)	(1.63)	(4.52)	(1.56)
N	97	97	97	97
R^2	0.246	0.331	0.269	0.332
adj. R^2	0.168	0.253	0.184	0.246

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$
Source: author, 2022.

Table 13. Models of Skills Access

	(1) lnskills	(2) lnskills	(3) lnskills	(4) lnskills
age	-0.00802***	-0.00646***	-0.0161***	-0.0147***
	(-3.35)	(-2.72)	(-4.62)	(-4.34)
female	-0.0106	0.0125	0.0466	0.0709
	(-0.16)	(0.19)	(0.70)	(1.10)
educ	0.111***	0.535***	0.0912***	0.522***
	(3.32)	(3.49)	(2.79)	(3.59)
income	0.00121	-0.0000963	-0.0760***	-0.0785***
	(0.11)	(-0.01)	(-2.79)	(-3.01)
nationality	0.0124*	0.00731	0.0139**	0.00877
	(1.70)	(1.01)	(1.99)	(1.28)
dutch	0.0457	0.0172	0.0321	0.00289
	(1.55)	(0.57)	(1.13)	(0.10)
english	0.148***	0.157***	0.151***	0.159***
	(4.14)	(4.52)	(4.40)	(4.83)
kids	0.0440	0.0334	0.0495*	0.0388
	(1.62)	(1.26)	(1.90)	(1.54)
employment	-0.0233	-0.0197	-0.0150	-0.0112
	(-1.05)	(-0.92)	(-0.70)	(-0.55)
educ2		-0.0679***		-0.0691***
		(-2.83)		(-3.03)
ageincome			0.00226***	0.00229***
			(3.08)	(3.26)
_cons	-1.066***	-1.569***	-0.778***	-1.285***
	(-4.20)	(-5.19)	(-2.99)	(-4.29)
N	101	101	101	101
R^2	0.497	0.538	0.544	0.587
adj. R^2	0.447	0.486	0.494	0.536

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$
Source: author, 2022.

Table 14. Models of Usage Access

	(1) usage_access	(2) usage_access	(3) usage_access	(4) usage_access
age	-0.000166	0.000202	-0.000142	0.0000354
	(-0.14)	(0.17)	(-0.12)	(0.03)
female	0.00385	0.0110	0.00116	0.000600
	(0.12)	(0.35)	(0.04)	(0.02)
educ	0.0398**	0.174**	0.0408**	0.0442***
	(2.56)	(2.38)	(2.60)	(2.86)
income	-0.000305	-0.000487	-0.0113	-0.00305
	(-0.06)	(-0.09)	(-0.60)	(-0.51)
nationality	0.00284	0.00127	0.000287	0.00336
	(0.84)	(0.37)	(0.05)	(0.97)
dutch	0.0101	0.00114	0.0103	0.0108
	(0.74)	(0.08)	(0.75)	(0.80)
english	0.0795***	0.0826***	0.0805***	0.0788***
	(4.68)	(4.91)	(4.70)	(4.47)
kids	0.00975	0.00686	0.0105	0.00574
	(0.78)	(0.55)	(0.83)	(0.46)
employment	-0.0180*	-0.0168*	-0.0172*	-0.0208**
	(-1.76)	(-1.66)	(-1.67)	(-2.05)
educ2		-0.0214*		
		(-1.88)		
raceincome			0.000724	
			(0.61)	
lanraceincome				0.00000194
				(0.13)
_cons	0.381***	0.221	0.411***	0.380***
	(3.16)	(1.51)	(3.13)	(3.16)
N	97	97	97	95
R^2	0.370	0.395	0.373	0.392
adj. R^2	0.305	0.325	0.300	0.320

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$
Source: author, 2022.

The significance of each demographic factors varies across levels of Access and according to the form of the model, in some of them the logarithmic transformation better explains the phenomena occurring in Carnisse; in others, the use of polynomials or interaction terms increases the models' explanatory power. In considering which models best explain the phenomena, this research considers the varying explanatory powers as well as which factors display consistent significance across models.

To address the complexity of the concept of the Digital Divide and to explain further possible reasons of the results, the following is an analysis of each level and each explanatory factor.

Motivational Access:
Model 2 is the model that best fits the level of Motivational Access, due the highest value of explanatory power among the rest, and due also to showing more significance of more factors. For the motivation access, age is associated with a negative effect on the probability of being motivated to use technologies, significant at 95% level, holding other factors constant. Education shows a positive effect as well, significant at 95% level, holding other factors constant. Having a higher level of Dutch language presents a positive effect with a 90% confidence level, as does having a better level of English. However, English ability presents a much higher effect and with a 99% confidence level; holding other factors constant, those with better English fluency will be more motivated to access. Employment type for this level is associated with a positive effect and it is also highly significant with a 99% confidence level. Additionally, it is important to mention that the model that best describes Carnisse is one with a log-lin transformation and using a polynomial square form of age, meaning that the fitted line is not linear. For this level, gender, income, nationality, and kids are not determinant factors; further analysis clustering the categories in each variable might be needed to understand the relation of these factors to the level.

Material Access:
For Material Access, the Model 2 is the one that better describes the level, with an explanatory power of 25.3%. The only significant determinant factors for this level are age and education, age with a negative effect and significant at a 99% confident level, and education with a positive effect with a 95% confidence level, holding other factors constant. In this case, the model does not use any log transformation, but it included a polynomial square term of age, meaning that it is not linear. The fact that income is not significant in any model of material access is also an interesting finding, reflecting that having devices is not related to having more purchasing power; this could be justified by two possible reasons. The first one is that the income in Carnisse also presents a gap: there are people having low income and high income but less in between. The second reason could be because of the status-quo of the market; technology is more standardized enabling people to buy a device for a low price. Gender, nationality, dutch, english, kids, and employment are not significant for this level, this could be due to the simplicity of the concept of having or not having devices or internet.

Skills Access:
For Skills Access the best model for describing the data is the Model 3 with a log-lin transformation of the dependent variable and a interaction term of age and income (ageincome). The selection of this model is due to the second highest explanatory power of 49.4% and the presence of more significance in more factors. Age for Skills Access is significant at a 99% confidence level and is associated with a negative effect on the inclusion in all the models,

regardless the model chosen, holding other factors constant, meaning that it is a strong determinant. Education is associated to an increase of the inclusion with a 99% confidence level; holding other factors constant, the more educated have higher skills access. Income on the other hand, presents significance at a 99% confidence level, but with a negative effect, contrary what is expected and described in theory. A possible theory for explaining the negative sign could be the fact that people with higher income have fewer practical reasons to focus on improving their digital skills as related to job prospects, for example. Regardless, more analysis should be done on the relationship between skills and income. Nationality is only significant in the level of Skills Access, not in the other three levels. This factor in this level is associated with a positive effect, with 95% confidence level; to better understand this effect, nationality should be studied in more depth. For example, it could be included via dummy variables that represent each nationality separately rather than together. Based on the fact that Dutch nationality comprises 62% of the sample, it can be inferred that the effect of the nationality variable is largely associated with the surveyed Dutch community. This result on nationality cannot be interpreted substantively because of the previous reasoning regarding low representativity of the rest of the nationalities. English, as in the rest of levels, presents high significance with a 99% confidence level and positive effect. Kids is the last factor with significance and shows a 90% confidence level with a positive effect. The interaction term ageincome shows 99% confidence level and also a positive effect, suggesting a reinforcing relationship between age and income.

Usage Access:

Finally for Usage Access, Model 4 is the better model, presenting a linear form of the fitted line and the second highest explanatory power of 32%. Education presents a positive effect with 99% confidence level, English as well and in this case, Employment type is also significant at a 95% confidence level, but with a negative effect. Employment type showed similar results in the motivation level, however, more in-depth and descriptive analysis is needed due to nature of the options within the variable, including responses from ‘employed’ to ‘retired’. Furthermore, the variable does not count consider other labor variables like sector. Age is not a determinant factor; this could be explained considering the linearity of the ADT model, where first the user needs to break and pass the first levels. This suggests that in Carnisse age does not determine the usage.

In addition to the models for each level, the analysis was conducted with the Digital Divide Index as the dependent variable. The results, in table 15, present the models that better fit the data and can explain the index. Age, Education, and the level of English are the only significant factors, with a negative effect of age, but positive effects of Education and English fluency, holding other factors constant. However, this index only evaluates on an overall level the inclusion in the neighborhood, meaning that the general explanation of the status-quo can be generalized with these models, but for deeper understanding it is useful to refer to the detailed analysis for each level of the divide.

Table 15. Models of Digital Divide

	(1) lndigitaldivide	(2) digital_divide	(3) lndigitaldivide	(4) digital_divide
age	-0.00479*	-0.00454**	-0.0128***	-0.00171
	(-1.89)	(-2.26)	(-3.03)	(-1.43)
female	0.00319	0.0264	0.0485	0.0113
	(0.05)	(0.80)	(0.70)	(0.35)
educ	0.0629*	0.0395**	0.0484	0.0472***
	(1.89)	(2.50)	(1.46)	(3.02)
income	0.000682	-0.0204	-0.0644**	-0.00359
	(0.06)	(-1.43)	(-2.15)	(-0.59)
nationality	0.00766	0.00453	0.00911	0.00398
	(1.06)	(1.34)	(1.28)	(1.15)
dutch	0.0153	0.00880	0.00456	0.0129
	(0.52)	(0.64)	(0.16)	(0.95)
english	0.115***	0.0590***	0.120***	0.0603***
	(3.10)	(3.42)	(3.31)	(3.34)
kids	0.0222	0.00778	0.0273	0.00226
	(0.81)	(0.61)	(1.02)	(0.18)
employment	-0.0273	-0.00654	-0.0235	-0.0108
	(-1.23)	(-0.63)	(-1.08)	(-1.03)
ageincome		0.000621	0.00193**	
		(1.58)	(2.33)	
lanraceincome				0.0000111
				(0.73)
_cons	-0.716***	0.571***	-0.453	0.480***
	(-2.75)	(4.31)	(-1.63)	(3.93)
N	95	95	95	93
R^2	0.293	0.352	0.336	0.354
adj. R^2	0.218	0.274	0.257	0.275

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$
Source: author, 2022.

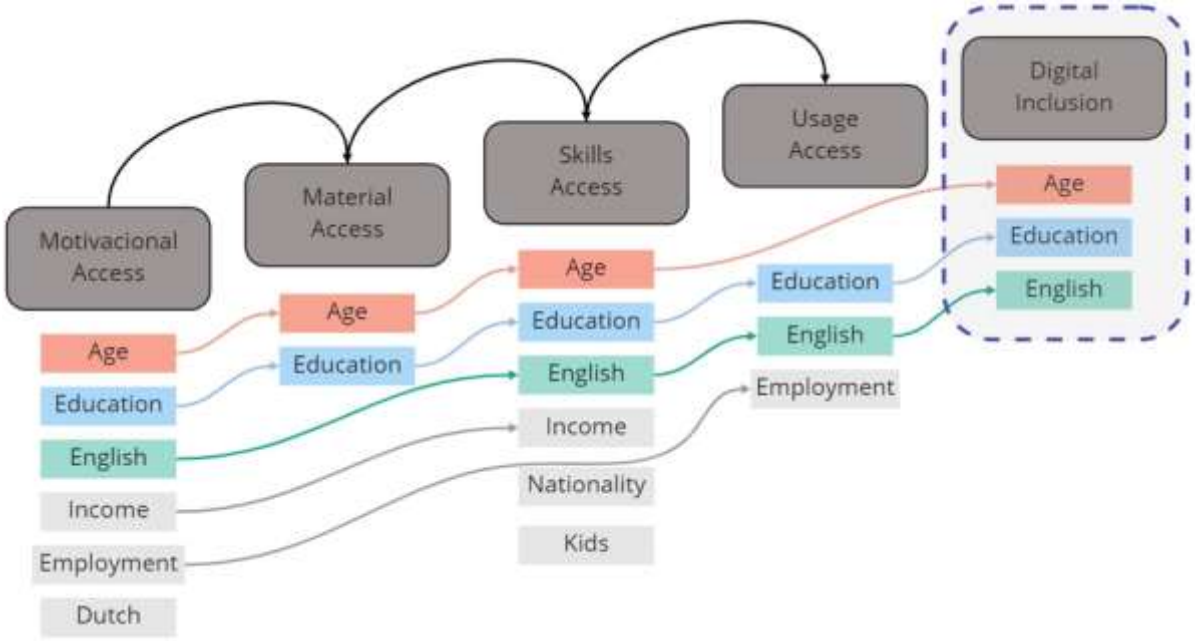
The best model to describe the digital inclusion in Carnise is Model 2, with a linear tendency it shows a 95% confidence level for age and education, and 99% confidence level for English. Additionally, the model presents higher explanatory power than Models 1 and 3, and similar to Model 4. Besides this, as mentioned in the literature, the methodology of an equal weight for every level is a socially acceptable practice, but different weighting could give more accurate results, especially knowing that more factors provide a description for Skills Access; this statement is further developed in the discussion chapter.

4.5. Summary of findings

4.5.1. Summary

To summarize the findings of the section above, the following chart 3 presents a diagram of which factors are significant and in which levels. Consistently, the main factors determining the digital divide in Carnisse are Age, Education and English, results which match the final model of the DD index. Certainly, the results and the analysis are more complex than just their significance, but significance concretely suggests which topics policy makers should address in order to improve the development of the neighborhood.

Chart 3. Summary of findings



Source: author, 2022.

4.5.2. Hypothesis testing

After clearly summarizing the data and analyzing the digital divide in Carnisse, the hypotheses presented in chapter one can be tested. As mentioned, the criteria for evaluating the hypotheses is based on the confidence, the explanatory power of the model, and the direction of the effect. The following table presents a summary of the data to test the hypotheses.

Table 16. Summary of data for hypothesis testing

Hypothesis	Level	Confidence	Effect	Adj-R^2
Ethnicity is highly significant explaining the Digital Divide of Rotterdam.	All	< 95%	+	0.274
Higher levels of education are related to low digital exclusion.	All	95%	0.0395	0.274
The older the person the more excluded from technologies, due to motivation	Motivation	99%	-0.0133	0.295
High income is related to more access to digital devices.	Material	< 95%	0.00515	0.253

Source: author, 2022.

Considering the results, for the first hypothesis, due to the low significance of the factor in the model on the digital divide index the hypothesis is rejected. However, as mentioned previously, the nationality in the sample confirms the superdiversity concept in the neighborhood, but the data is not representative enough to test the models for each of the nationalities individually. Despite this, even with rejection of the hypothesis, to better understand of the role of the factor in the Digital Divide more analysis is needed. In the future, cluster analysis grouping the nationalities in regions or continents to see if there is more relevance of in the sample would be valuable. Running regression analysis using dummy variables for each nationality is also possible, but this has the same problem of representativeness, consequently, the best way to better understand ethnicity is collecting more data.

For the second hypothesis, the significance is 95%, the effect is positive and the Adjusted R^2 is high enough compared to the rest of the models. Therefore, this research fails to reject the

hypothesis, confirming that in Carnisse, Education plays a significant role in the digital divide. In other words, higher levels of education are associated to more digital inclusion, on the contrary lower levels is associated to more exclusion, holding other factors constant.

For the third hypothesis, with a negative coefficient, a reasonable Adjusted R^2 and with a 99% confidence level, this research fails to reject the hypothesis. It is confirmed that in Carnisse, indeed age plays a negative role in digital inclusion, in particular, being older reflects less motivation, holding other factors constant.

For the final hypothesis, the significance level is less than 95%, meaning that this research rejects the hypothesis. Contrary to what was expected, more income is not associated to more access to internet or to digital devices. This could be because the access is considerably high with more than 97% of the sample having material access, and it could also be because the status-quo of the market of technology is more standardized, enabling people to buy a device for a low price.

4.5.3. Digitally excluded, profile

To finalize the analysis and as stated in the second sub-research question, understanding who is digitally excluded in Carnisse will provide the final piece of information to understand the digital divide in the context of Carnisse. The levels that were measured and the DD index largely describe who is included, rather than who is excluded. So, it can be inferred that the information that falls outside those descriptions is the information that might characterizes the digital exclusion gap. Nevertheless, knowing which factors determine inclusion can explain which factors policymakers need to reinforce in order to lower the exclusion.

In terms of the profile of who is excluded in Carnisse, as explained in the summary statistics of the demographic factors and in relation to the regression analysis, this research points that young adults between 20s and 40s are more included than the older people, suggesting a potentially excluded group of those older than 40. Regarding education, the people with less than secondary degree require particular focus. Considering English fluency, individuals that do not know the language or are beginners would be another target.

Chapter 5: Discussion

In this section of the research, we already describe each level of the digital divide, and we have already created an index to score the neighborhood that describes the status-quo of Carnisse. However, there are some main takeaways of the research that need to be discussed through a critical focus.

First, the score of Digital Inclusion of Carnisse with 79,9% is comparable to the scores of NRI and some of the pillars of DESI, both measuring the average digital inclusion in the country. This comparison means that the tool of measurement is accurate and functional, however, the result was not the expected for the neighborhood. Carnisse, considered to be the neighborhood with the lowest social performance, was expected to score lower than the overall country average. Although the indices are calculated differently, it was expected to obtain a more pronounced digital gap. It is too early to conclude that the digital divide in Carnisse is not so conspicuous based solely on country-level indices, it is necessary to analyze other neighborhoods in the same way in order to have a parameter for comparing the results; it is also necessary to interpolate the result with other types of social divides that have already been calculated.

In the same train of thought, second, the comparison between the results and the literature shows that indeed all the demographic factors can somehow explain the concept of DD; but the literature does not explain why they are influencing the gap. When Van Dijk presented his model, he discussed for each level the barriers to accessibility, and the possible determinants of a negative digital gap, focusing mainly on how the factors were increasing the digital gap, not on the reasons. It is clear that by dividing the concept into levels it is easier to appreciate the specific effect of each of the demographic and social factors, but by unifying it again in the form of an index some of the determinants are lost. For example, Income is a determinant describing the skills access but is not when describing the DD in Carnise. To solve this, a possible inverted approach could be considered; instead of studying the barriers and the reasons of the people who are digitally excluded, studying the reasoning of those who are included would provide two possible outcomes: first, a more representative sample, and second more practical and concise policy recommendations through copying behaviors.

On the other hand, even if the result of the Digital Divide Index is comparable to widely accepted indices; and the determinant factors found are comparable with the theory, the methodology built through the ADT model cannot be put aside. It is a robust methodology that unbundles the concept of DD and allows for measuring each level. This methodology presents a certain level of novelty lies in its simplicity and practicality. Van Dijk in his articles use the same model as a way of measuring the divide and proposed variables in each of the levels but the variables are limited or more complex for practical purposes: an example of this is the skills proposed by Van Dijk to measure the Skills Access, he proposed Computer skills, Instrumental skills, operational skills and he add strategic skills (Van Dijk, 2006); these categories lack of explanation on how are they measured. In contrast, our methodology with 5 types of skills organized in increasing difficulty levels allows us to facilitate the process of data collection and analysis. Even though the self-reporting nature of the survey is still a limitation, the outcomes are promising results and finding, meaning that the tool of collecting data and the technique of analysis work efficiently.

In addition, the methodology of creation compound variables and indices is a current debate, due to the level of importance of each variable. This research selected weighs of the variables based on arithmetical relations and simple equal divisions based on summary statistics of the data, meaning that the calculation of the weights always considers the essence of the topic.

Models such as Item response theory (IRT) or computational creation variables were reviewed, but since they consider the frequency of the responses, they put aside the topic. Explaining more, computational models use an equal distribution based on some basic measurement like the mean, but still understanding the data is the best way to create compound variables.

Regarding the models created to define which factors are significant, it is not possible to select a specific one due to the differences of each variable. For example, the models of Material Access were more linear compared to the models of Skills Access that used log-lin transformations and polynomials and interaction terms. Even though the theory mentioned that the best way to quantify the digital divide is with a log-lin transformation, Material Access shows the contrary, meaning that is not about creating a standard method of measurement, is about considering each case study to define the way of measuring of the digital divide.

Chapter 6: Conclusions

The results and findings of this research support the literature on the topic but still demonstrate some differences due to the nature and characteristics of the analyzed neighborhood. After reviewing the literature, analyzing the summary statistics, and conducting regression analysis of primary data collected is clear which demographic and social factors explain the digital divide among the people of Carnise. The special focus on creating an index and assessing the neighborhood allowed to generate an overview of the status-quo of Carnisse, but beyond that, through the methodology implemented and through the debate this research contributes to the understanding and the measurement of the concept with a novel approach and possible new interpretations for future policies. Reviewing the objectives and research questions, the following main takeaways were determined.

Upon review of the objectives, each of them was satisfactorily met. The Digital Divide was described in the context of Rotterdam, especially Carnisse as a division of access to technologies due to age, education, and knowledge of English. The definition was presented and explained, concluding that the best way to measure the divide is with a multivariate conceptualization due to the complexity of a city such as Rotterdam. Subsequently, it was possible to identify that in Carnisse the most present level of inclusion is the Material level with 97%, and on the contrary referring to the digital gap the lowest level was the Motivation level with 72% of inclusion due to age, Education, English, Income, Employment, and knowledge of Dutch. Additionally following the fourth objective it was determined that Age, Education, and English were the stronger determinants but each of the factors determines different levels increasing or decreasing the gap. These three factors are the ones that policies should address.

Moreover, the first sub-research question of which model of measurement of the digital divide is most applicable in the context of Rotterdam, in chapter 2 reviews the different conceptualizations of the Digital Divide and how starting with a basic definition as a social gap based on access, the concept evolved to a more complex definition adding levels. For the Dutch context, we concluded that the ADT model of Van Dijk presents a broader definition of the DD considering more social aspects that describe it practically. Van Dijk's model when considering four levels in a linear way is defining the gap and setting milestones for the Dutch society.

The second sub-question about the demographic and social of the population exposed to the DD was covered with the summary statistics. With the description of the data, a profile was created, concluding that those who are not excluded are young adults between 20 and 40 years with at least a secondary degree. More description can be included when considering a dummy analysis of variables like employment or kids, concluding that people with full-time jobs and with none to a maximum of 2 kids are also included, but due to the low polarity of the variable in the sample more in-depth analysis is needed to verify these last characteristics. On the contrary, those who are digitally excluded are people who are older than 40 years old, retired, and with low education. that gender and kids do not count in the creation of the profile creation.

The last sub-question about the main possible factors explaining each one of the levels was extensively addressed and is summarized in Chart 3. The results obtained are for motivational access Age, Education, English, Income, Employment, and knowing how to speak Dutch; for material access Age, and Education; for skills Age, Education, English, Income, Nationality, and Kids; and for usage access Education, English, and Employment.

In addition, other findings were obtained as part of the research process, these are listed below:

- The theory of the digital divide presents Age, Income, Education, Nationality, Gender, Language, or Employment as the main demographic factors explaining the concept. In conclusion, it was demonstrated that indeed they explain the concept in the context of Carnise, but on different levels. Refer to sub-question 3.
- The methodology for measuring the digital divide is unclear, there are several models with bivariate approaches and some with the multivariate approach. For the study of a city, in this case, the neighborhood of Carnisse a multivariate approach is necessary but not sufficient.
- The Model of Accessibility to Technology (ADT) presented by Van Dijk (2005), Is still applicable and presents an extensive view of the concepts through the 4 levels, however, is a linear model of accumulative nature that falls on explaining social behavior.
- Through the discussion, the Digital divide concept was criticized due to the deterministic approach of aiming the 100% of inclusion, also due to the normative approach of thinking in groups digitally excluded instead of individuals. To address this also each level of the ADT was criticized to propose a new vision for more effective policy making, being this positive vision the study of those who are digitally included and the reasons why they are included, instead of studying the barriers as it has been done

Finally, we conclude that the Digital Divide Index is just a general attempt to categorize and compare Carnise with the rest of the country, but a more similar analysis should be done in other neighborhoods to better understand the context of Rotterdam.

Policy recommendation

Regarding the policy recommendations, based on the obtained results Education, Age, and knowledge of English should be the main factors to have into consideration. Reinforcing educational programs in the neighborhood, giving financial support for education, and scholarships are key points to consider, but those are already part of a broader agenda of the city; however, a city-focused initiative will be reflected in a decrease in the digital divide. Moreover, English is a highly significant variable, the educational programs should consider strong and accessible language teaching programs. These basic policies recommendations should be part of the long-term agenda.

More in detail, between the four levels, motivational access was the one with a lower score meaning that the population of Carnisse that is more exposed to a lack of motivation. The determinants of motivations, as explained are not only anxiety or stress, but are more to an educational perspective of the possible outcomes of new technologies and the possible improvements in their social lives. This recommendation would be addressing the psychological part of the elderly with a focus on connectivity and communication and would generate a sense of belonging that could reduce the digital gap. Besides this, developing programs on material access as a cyber bank, according to the findings is not needed due to high accessibility, it is better to redirect efforts to a lower level of motivation or to scale up to a skills level with a focus on developing networks of knowledge.

Appendix 1: Research instruments and time schedule

Annex 1. Digital Divide Questionnaire

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DIGITAL DIVIDE QUESTIONNAIRE

Today, many sources of information and various services are available online. This increasing digitalization affects different people in different ways. This survey is part of a larger research project about personal skills and usage of digital devices (such as computers and smartphones), the internet, and online services, as well as their benefits and limitations.

Below you will be asked to give your perception of various topics related to our research. With your answers, we will analyze who the digitalization of information and services affects and how it affects them. Some questions will be simple to answer, others you might be more uncertain about. Please answer to the best of your ability; we want to capture your main feelings and opinions.

Thank you for your help with this important project!

1. SOCIAL PERCEPTIONS

For the following statements, please rate your agreement from 1 (strongly disagree) to 5 (strongly agree).							
SOCIAL INCLUSION	1	2	3	4	5	N/A	Don't know
I consistently participate in my community (e.g., volunteering, cultural festivals, neighborhood meetings, etc.).							
I feel that my social needs, problems, and circumstances are considered by the municipality.							
PERCEPTION OF STEREOTYPES	1	2	3	4	5	N/A	Don't know
There are stereotypes about different kinds of people based on their identity (gender, ethnicity, etc.).							
I personally experience bias or discrimination because of my identity (gender, ethnicity, etc.) in my daily life.							
I personally experience bias or discrimination because of my identity (gender, ethnicity, etc.) in work or education.							
There are stereotypes about digital usage (of computers, smartphones, the internet) and abilities specifically related to a person's **gender**.							
I personally experience bias or discrimination regarding my digital usage and abilities because of my **gender.**							
There are stereotypes about digital usage (of computers, smartphones, the internet) and abilities specifically related to a person's **ethnicity**.							
I personally experience bias or discrimination regarding my digital usage and abilities because of my **ethnicity.**							

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2. MATERIAL ACCESS

What types of devices do you have access to at home? (Check all that apply).

- ☐ Desktop computer
- ☐ Laptop
- ☐ Smartphone
- ☐ Tablet
- ☐ Other
- ☐ None

If applicable, how many of each device do you have at home?

- ☐ Desktop computer
- ☐ Laptop
- ☐ Smartphone
- ☐ Tablet

Do you have reliable access to an internet connection at home?

- ☐ Yes
- ☐ No

In the past 30 days, where have you used the Internet? (Check all that apply).

- ☐ At home
- ☐ At work, school, or university
- ☐ While traveling (e.g., on a bus, tram, or train)
- ☐ Somewhere else (e.g., library, internet café, at another person's house)

3. DIGITAL USAGE

I have an e-mail address.

- ☐ Yes
- ☐ No

How often do you use the internet?

☐ Never | ☐ Less than once a week | ☐ Once a week | ☐ 2-3 days a week | ☐ 4-6 days a week | ☐ Daily

How often do you use online software or applications (Word, Excel)?

☐ Never | ☐ Less than once a week | ☐ Once a week | ☐ 2-3 days a week | ☐ 4-6 days a week | ☐ Daily

In the past 12 months, for what purposes have you used the internet? (Check all that apply).

- ☐ Music/video streaming services
- ☐ Gaming
- ☐ Leisure internet searches (e.g., blogs, travel)
- ☐ Practical internet searches (e.g., recipes, childcare, healthcare)
- ☐ Online courses or training
- ☐ News (e.g., articles, videos)
- ☐ Finding/applying to jobs
- ☐ Online shopping
- ☐ Reading product reviews
- ☐ Social network sites
- ☐ Sharing photos/videos
- ☐ Other: _____

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4. SKILLS

For the following statements, please check yes or no according to your personal abilities.		
OPERATIONAL SKILLS	Yes	No
I know how to connect to a WIFI network.		
I know how to look for information online using a search engine.		
I know how to install apps on a mobile device such as a phone or tablet.		
I know how to download files and retrieve them once saved or stored.		
I know how to attach files to an email.		
I know how to complete online forms.		
I know how to avoid computer viruses.		

To what extent are the following statements true of you? Please answer from 1 (not at all true of me) to 5 (very true).							
INFORMATION SEEKING SKILLS	1	2	3	4	5	N/A	Don't know
I find it easy to decide the best keywords to use in online searches.							
I find it easy to use and navigate most websites.							
SOFTWARE/CONTENT CREATION SKILLS	1	2	3	4	5	N/A	Don't know
I know how to change the settings of a digital device or application.							
I know how to find, download, install, and configure applications.							
I know how to produce or edit content using a word processor (e.g., Word).							
I know how to produce or edit spreadsheets (e.g., using Excel).							
I know how to use basic formulas in a spreadsheet.							
I know how to create digital presentations (e.g., using PowerPoint, Canva).							
I know how to produce or edit simple digital content like images, memes, videos, and/or audio files.							
I know how to use specific software for design, calculation and/or simulation (e.g., Photoshop, AutoCAD, Aicon, etc.).							
SAFETY & SECURITY SKILLS	1	2	3	4	5	N/A	Don't know
I check if the information and websites I access online are trustworthy.							
I know which information I should and should not share online.							
I feel safe sharing my information online for services such as the municipality online portal or subscription websites.							

For the following statements, please rate your perception from 1 (low) to 5 (high).							
PROBLEM-SOLVING SKILLS	1	2	3	4	5	N/A	Don't know
My ability to solve routine problems with my devices (e.g., close program, restart computer, reinstall/update program, check internet connection) is:							
My ability to find support and assistance when a technical problem occurs or when using a new device, program, or application is:							
PERCEPTION OF DIGITAL INCLUSION	1	2	3	4	5	N/A	Don't know
Compared to others, my personal skill level using digital devices and/or the internet is							
My personal level of stress or anxiety about using digital devices and/or the internet is:							

For the following two statements, please rate your agreement from 1 (strongly disagree) to 5 (strongly agree)							
MOTIVATION/ATTITUDES	1	2	3	4	5	N/A	Don't know
Having access to the internet and digital devices has improved my life.							
My knowledge has increased because of the Internet (e.g., looking up information, talking to others online).							

5. FINANCE

For the following statements, please evaluate your personal usage frequency							
DIGITAL FINANCIAL USAGE	Never	Rarely	Sometimes	Frequently	Always	N/A	Don't know
I use a digital bank account.							
I pay with a card or QR code (cashless).							
I use a digital financial app (e.g., Tikkie, Revolut, Bux).							
I use digital financial investments (e.g., stocks, cryptocurrencies).							

For the following statements, please check yes or no according to your personal perceptions.		
FINANCIAL ACCESS, USE, AND PERCEPTION	Yes	No
I find it easy to use digital financial solutions e.g., Tikkie, PayPal, split wise.		
I trust financial technology solutions such as Tikkie and Revolut.		
I look for interest rates and investment opportunities on the internet.		

How many digital bank accounts and/or wallets do you have?

In the past 5 years, I have applied for a loan (of any type or amount):

☐ Online ☐ At the bank branch ☐ I have not applied for a loan

6. LABOR

In the previous 12 months, what was your average household gross monthly income?

☐ €1350 or less
☐ Between €1350 and €1850
☐ Between €1851 and €2350
☐ Between €2351 and €2850
☐ Between €2851 and €3350
☐ Between €3351 and €3850
☐ Between €3851 and €4350
☐ Between €4351 and €4850
☐ Between €4851 and €5350
☐ More than €5350

What is your employment status? (Can check multiple)

☐ Full-time employed
☐ Part-time employed
☐ In education
☐ Caregiver
☐ Unemployed
☐ Retired
☐ Not looking for work

IF EMPLOYED, what type of contract do you have?

☐ Temporary
☐ Permanent
☐ Other: _____

For the following statements, please select what is applicable to you.		
Please mark the occupations in which you are working now and/or in which you have worked in the last five years (multiple selections allowed).	**Current occupation** (mark only if you are currently employed)	**Last five years**
Building, craft, and related trade workers		
Plant machine operators and assemblers		
Sales, customer, or personal service workers		
Technicians		
Clerical support workers		
Skilled agricultural, forestry, and fishery workers		
Professionals		
Managers		

For the following statements, please select what is applicable to you.		
Please mark the sectors in which you are working now and/or in which you have worked in the last five years (multiple selections allowed).	**Current sector(s)** (mark only if you are currently employed)	**Last five years**
Agriculture, forestry, and fishing		
Manufacturing		
Electricity, gas, steam, and air conditioning supply		
Construction		
Wholesale and retail trade; repair of motor vehicles and motorcycles		
Transportation and storage		
Accommodation and food service activities		
Information and communication		
Professional, scientific, and technical activities		
Administrative and support service activities		
Education		
Human health and social work activities		

Considering your employment history, please answer the following questions.			
JOB STABILITY	Yes	No	N/A
In general, it has been difficult for me to find a job.			
In the past, I have had periods of unemployment.			
In the past, I have had difficulties finding a job because of my digital skills.			
I currently use digital devices in my job.			

7. ONLINE SERVICES

For the following statements, rate your agreement from 1 (strongly disagree) to 5 (strongly agree). Some municipal services include paying Council Tax, completing passport renewal, receiving a driving license, registering to vote, applying for public school.							
PERCEPTION OF MUNICIPAL SERVICES	1	2	3	4	5	N/A	Don't know
Most municipal services are offered online.							
I find online municipal services useful in my daily life.							
My interaction with online municipal services is clear and understandable.							
I prefer online services to in-person services.							
I would like to improve my ability to access online services.							

If the city of Rotterdam were to offer services for residents to improve their digital and internet skills, what format(s) would you prefer? (Check all that are of interest to you).

- ☐ Walk-in (no registration required)
- ☐ Requires prior registration

What type of assistance would you prefer?

- ☐ Once-weekly class (short – approx. 1 hour)
- ☐ Once-monthly workshop (long – approx. 2 to 4 hours)
- ☐ Office hours multiple times per week (open availability to ask someone for help)
- ☐ Other: _____

What location would you prefer? (Check all that are of interest to you).

- ☐ Neighborhood school
- ☐ Local library
- ☐ Local religious center
- ☐ Community center
- ☐ Other: _____

What days of the week would you prefer? (Check all that are of interest to you).

- ☐ Weekdays
- ☐ Weekends

What time frame would you prefer? (Check all that are of interest to you).

- ☐ Morning (9:00-12:00)
- ☐ Afternoon 12:00-15:00
- ☐ Late afternoon 15:00-18:00
- ☐ Evening 18:00-21:00
- ☐ Other: _____

8. GENERAL INFORMATION

How old are you?

☐

What is your gender?

☐ Male ☐ Female ☐ Other ☐ Prefer not to say

How many children under the age of 18 live with you?

☐

What is your level of education (or equivalent)?

- ☐ Primary education
- ☐ Secondary education (VMBO, VWO, HAVO)
- ☐ Bachelor's degree – Vocational (HBO, MBO)
- ☐ Bachelor's degree – Academic (WO)
- ☐ Master's degree or higher

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What is your nationality? (Can list multiple).

What are your parents' places of birth?

Father	
Mother	

Do you have a DigiD?

☐ Yes ☐ No

In the past 12 months, have you used your DigiD to access any government services, information, etc.?

☐ Yes ☐ No

What is your native language? (Can list multiple).

IF YOUR NATIVE LANGUAGE(S) ARE NOT DUTCH OR ENGLISH,

Do you speak Dutch and at what level?

☐ Beginner ☐ Intermediate ☐ Advanced ☐ Fluent ☐ N/A

Do you speak English and at what level?

☐ Beginner ☐ Intermediate ☐ Advanced ☐ Fluent ☐ N/A

Are you registered with the Municipality of Rotterdam?

☐ Yes ☐ No

What is your zip code? (First four numbers only, e.g., 3073.)

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