PROJECT ON SMART MOBILITY IN RURAL AREAS

A case study on improving accessibility and connectivity in public transport by applying smart mobility solutions in the area of Schouwen-Duiveland, the Netherlands

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Disclaimer: The report is based on the investigation of a bachelor student group in an 8-week time frame; more research is needed for real-world applications. Furthermore, the data for this report is hand-made based on external sources. No scientific researcher is done to verify the data. The authors take sole responsibility for all views and opinions expressed in this report.

SUMMARY

Nowadays, offering an efficient public transportation system in rural areas faces many challenges. By using Schouwen-Duiveland as a case study, this problem will be analyzed. After analyzing the current situation and using externally obtained data, a new mobility service system was designed by applying smart solutions including smart hubs and tele-busses. This design was then assessed based on design objectives which were determined in advance.

"People always expect you to be riding around in stretch limousines all the time, but I will sometimes take public transportation if it's convenient, and it does surprise people, you see the heads turn."

Paul McCartney

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1. INTRODUCTION

Mobility enables people to get access to health care, education, work, shops and other important locations and services. It offers economic and social opportunities for people and should therefore be available for everyone. A common mobility problem is that "rural communities face a range of challenges associated with accessibility and connectivity" (Nagendra, 2012). Inhabitants of rural areas are often very dependent on private vehicles, due to the poor quality of public transport systems and the relatively long distances to access basic needs (Rij-instructie, 2016). Also, facilities such as football clubs and primary schools are being clustered more and more nowadays, which makes mobility (and especially public transport) increasingly important, as not everyone lives near these clustered areas (Gemeente Schouwen-Duiveland, 2017). These problems mostly affect people without a car such as students and the elderly, while these people have needs to travel as well (Ministerie van Infrastructuur en Waterstaat, 2019). It is therefore important to provide a mobility service that is accessible to everyone to engage in economic and social activities.

These problems have a deep, negative impact on society. For example, when children cannot easily get access to a secondary school they remain uneducated, leading to an increase in people with low qualifications in rural areas (Coughlan, 2017). Another big issue is that because of this poor connectivity the young are leaving rural areas and therefore these areas face the problem of aging (Litman, n.d.)

In order to further investigate this problem and to find a fitting solution, this project will examine the rural area Schouwen-Duiveland as a case study. Schouwen-Duiveland is a Dutch island located in the province of Zeeland. In the rest of the report this case will be used to address the problems in rural areas.

1.1 BACKGROUND

To gain a thorough understanding of the mobility problem in the municipality of Schouwen-Duiveland, the socio-demographics and the current transport mode distribution will be examined in this section.

1.1.1 Socio-Demographics

Table 1 shows a comparison between the current situation in Schouwen-Duiveland and the averaged situation in the Netherlands based on relevant socio-demographic indicators. The references of the exact numbers can be found in Appendix A.

Table 1 – Comparison of social-demographic indicators

	Schouwen-Duiveland	The Netherlands
Male (%)	49.5	49.7
Female (%)	50.5	50.3
Age group 01-14 years (%)	13.9	15.7
Age group 15-24 years (%)	10.3	12.3
Age group 25-44 years (%)	18.9	24.8
Age group 45-64 years (%)	30.0	27.8
Age group 65+ years (%)	26.9	19.4
Single person households (%)	33.4	36.8
Households with children (%)	29.8	25.6
Households without children (%)	36.7	27.7
Population density (inhabitants per km2)	147	504
Cars per household	1.2	0.9
Distance to general practitioner (in km)	1.4	1.0
Distance to supermarket (in km)	1.3	0.9
Distance to daycare (in km)	1	0.9

Several conclusions can be drawn from Table 1. The first point of attention relates to the relatively large group of elderly people in Schouwen-Duiveland. The age group of 65+ years is clearly above average when being compared to the average of the Netherlands. This aging concept could have consequences for the mobility situation. For example, aging is often associated with a decline in physical abilities, making it harder for the elderly to walk, cycle, or drive a car (Shergold et al., 2015). This might increase the dependence on public transport which leads to an increase of the demand for a good public transportation system.

Secondly, the low population density of Schouwen-Duiveland stands out, indicating that the island contains a low number of inhabitants for its land area. Figure 1 provides information about how the population is distributed on the island, marking Zierikzee and Haamstede as the two locations with the highest number of inhabitants. Figure 2 shows the distribution of the trips being made on Schouwen-Duiveland. Four areas seem to attract a relatively high number of trips. These areas are indicated with the following numbers: 1 (Renesse), 8 (Haamstede), 13 (Nieuwerkerk) and 15 (Zierikzee). These areas belong to the eight locations in Schouwen-Duiveland that have a population larger than 1000 (CBS, 2019). Areas that have almost no attraction of trips are 11 (Noordgouwe) and 7 (Serooskerke), having a population of respectively 315 and 270 (CBS, 2019). Therefore, there is a connection between the number of inhabitants and the amount of attracted trips. Figure 2 also indicates that the larger villages on the island are more oriented on their own center than the smaller villages, which is probably why people from the smaller villages are traveling towards the larger ones.

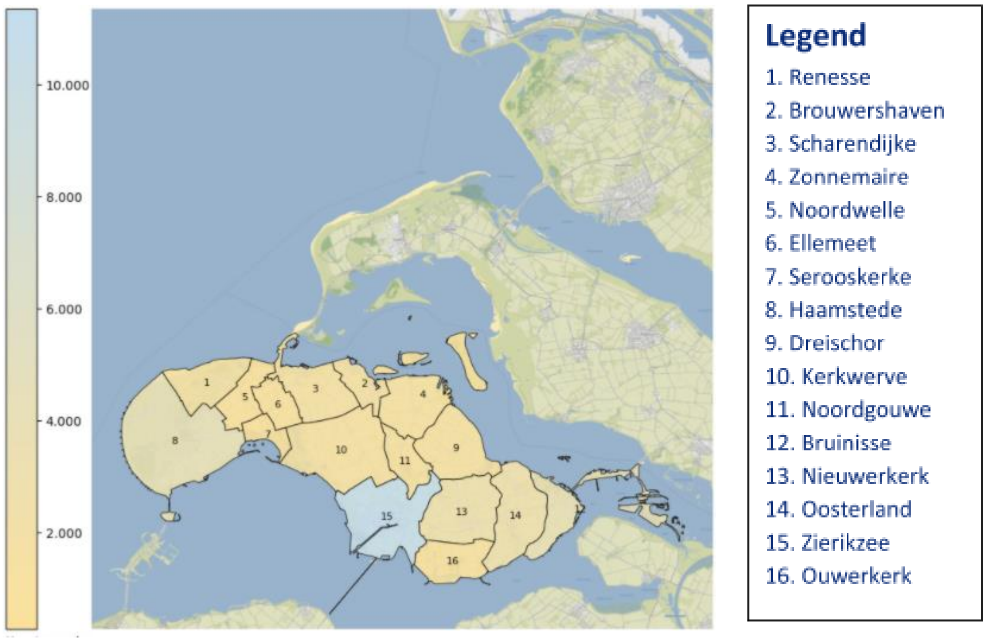


Figure 1 - Density distribution of inhabitants (AlleCijfers.nl, 2020)

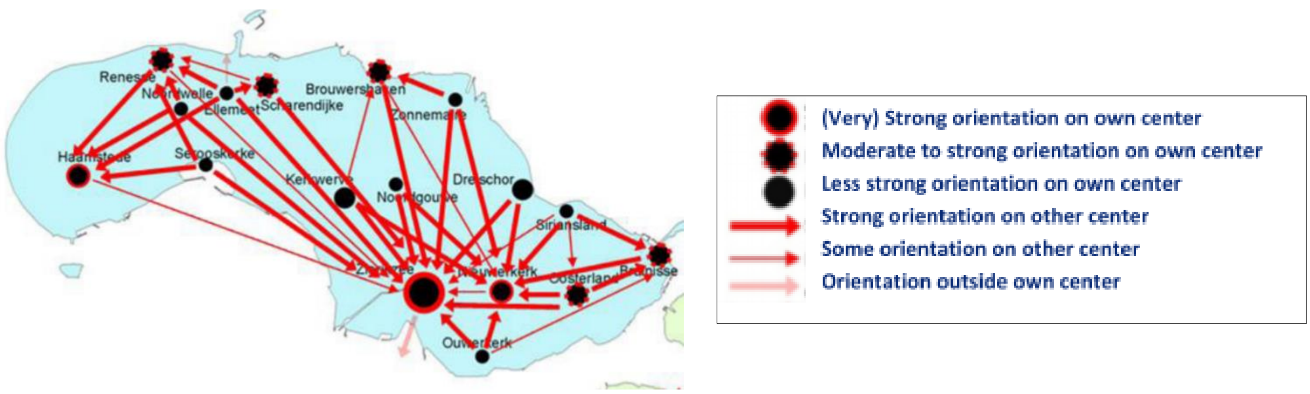


Figure 2 – Trip Orientation (Smit & Clement, 2013)

The last notable issue retrieved from Table 1 is about the fact that inhabitants of Schouwen-Duiveland have to travel further to reach a general practitioner, supermarket, or day care center. As the island has a low population density, it is not profitable to have all facilities present in every village (CBS, 2016). Take for example Serooskerke Schouwen, this village does not have a supermarket as this is not profitable due to the low number of inhabitants. However, the inhabitants still need to buy groceries and therefore they will travel towards other villages which do have the facilities they need, such as a supermarket. This increases the travel distance for different basic facilities, which is included in Table 1.

Furthermore, the island is connected to other islands by means of three dams and a bridge. This enables traffic to reach the surrounding islands, and via these islands access to the mainland is provided. There are no train connections available on the island, as there is no railway.

1.1.2 Transport Mode Distribution

The mentioned basic facilities can be reached by multiple transport modes, like for example by car, bike, or public transport. To gain insight into the current transport mode distribution on Schouwen-Duiveland, there will be examined which transport modes are being used on the island and to what extent. As it is hard to gather exact data on the existing transport mode usage of the inhabitants of Schouwen-Duiveland, data about the whole province of Zeeland (ZL) (Provincie Zeeland, 2016) are used and compared to data about the average in the Netherlands (NL)(CBS, 2017)(CBS, 2018) in Table 2.

Table 2 – Daily Transport Mode Distribution

Private transportation	ZL 2016	NL 2017	Public transportation	ZL 2016	NL 2017
Car	49%	47%	Bus	1%	3%
(Motor)bike	29%	27%	Train	1%	3%
Walking	18%	18%			

All available transport modes are divided into the two categories: private transportation and public transportation. The percentages show how many inhabitants use the different transport modes on a daily basis. When comparing Zeeland and the Netherlands as a country, no significant differences occur. One conclusion, however, inferred from Table 2 is that the focus on private transportation is slightly higher within Zeeland when comparing this to the average of the Netherlands, when looking at public transportation, it is the other way around. Other research (Smit & Clement, 2013), based on stated preference data, shows the results of interviews about transportation with the inhabitants of Zeeland. It was concluded that 53% of the interviewees travel by car more than 4 times a week, while only 8% say to use public transport frequently, which contributes to the idea that public transport is underrepresented in Zeeland. The study also established that both young (younger than 23 years) and old (older than 80 years) people are daily users of public transport. It should be noted that the public transport here means busses, as there are no trains on the island.

Besides, more than 10% of the population of Schouwen-Duiveland that is allowed to own a car, does not own one and are therefore in need of alternative transport modes. People that are not able to use any form of transport by themselves can make use of 'Doelgroepenvervoer' (target-group transportation), which is a transportation mode that enables disabled people to move throughout their environment. Doelgroepenvervoer is often a demand-responsive transport system in which the users can order their trips in advance (Smit & Clement, 2013).

1.2 PROBLEM DEFINITION

Combining the social demographics and transport mode distribution of internal and external traffic provides a clear view on the mobility situation of Schouwen-Duiveland. It became clear that the island is car-dependent and therefore, the usage of public transport is not that high. In this section the problems related to the public transport in the area will be addressed.

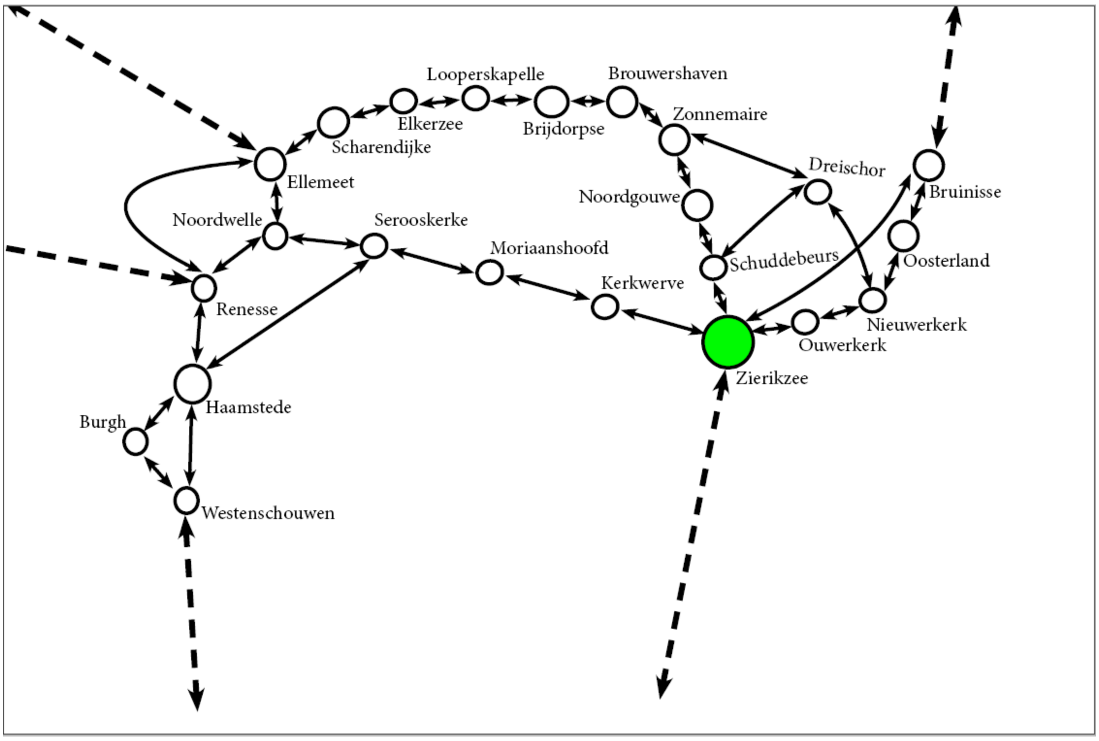


Figure 3 – Abstract representation of current Public Transport Network

The problem can be divided into several main elements. The first one, indicated by passengers participating in focus groups, is the relatively long travel time of public transport (Ministerie van Infrastructuur en Waterstaat, 2017). The long travel time is caused by the detouring of fixed routes of the busses, which is visualized in Figure 3. For example, if someone wants to travel from Brouwershaven to Serooskerke by public transport, no direct route is offered and said person has to detour via Ellemeet or Zierikzee, which is far from efficient. Data on the current travel time, distance by road, amount of transfers required to travel and the amount of inhabitants per village has been generated and can be found in the file that contains the data of this report, under the tabs “Time old”, “Distance old”, “Connectivity old”, “Accessibility old”, and “Weights”. At the end of this report this data will be compared with the newly generated data that takes the final solution into account to measure the progress. Another problem related to the current bus system, is that not all the villages in Schouwen-Duiveland can be reached by public transportation, causing bad connectivity and accessibility for certain villagers.

Next to that, the report of Ministerie van Infrastructuur en Waterstaat of 2017 notes that when people are traveling by public transport, their trips are too often experienced as of poor quality. The bus does not show up or has a delay on a regular basis. In addition to this, communication with staff leads to problems sometimes. Bus drivers seem to be annoyed and hurried and sometimes unfriendly to (disabled) passengers. Also, not everyone is aware of other public mobility options, such as Haltetaxi, which could be ordered by phone or email. The lack of sufficient knowledge and digital skills can make the planning of a trip difficult for the elderly.

There are also some less important but still relevant problems. For instance, because of commuters and students, busses seem to be rather crowded in the morning and afternoon, causing an uncomfortable situation, while during the rest of the day there is lots of space. However, planning for peak hours is a challenge as increasing the capacity will lead to under-used busses outside peak hours. Another problem is that the discount card for elderly (65+ card) is valid only after 9:00 AM, so after the rush hour in the morning. This has probably been done to decrease the pressure during peak hours, but by doing so, the elderly are being secluded. The peak hours with full busses and the space during other times of the day indicate a supply and demand mismatch.

1.3 LITERATURE REVIEW

In (Vartiainen et al., 2018) the following is stated: ‘Future mobility strategies should therefore focus on the development of new mobility services in the outskirts and rural areas. This could be achieved by improving the access to the public transport network and by promoting less traditional forms of transport means such as call-a-ride, ride-sharing, carpooling, MaaS and so on.’ In this chapter, some smart technologies will be discussed that could be a solution or a part of a solution to our problem regarding the bad connectivity of Schouwen-Duiveland. Smart technologies are technologies which are new, innovative, adaptive and manageable by suitable assumptions.

The first considered smart technology could be a solution to the mismatch of demand and supply within the area of Schouwen-Duiveland. The idea is a demand-responsive transport (DRT) system. DRT is a public transportation service that combines regular bus routes with highly personalized taxi-like options (Mageean et al., 2003). The traveled routes are not fixed, but will be modified to the needs of the user, which the user can indicate in an application. DRT is a smart technology because of the new use of apps and fast ways of processing the demand. It is manageable since it has already been successfully implemented in other regions. The advantage of such a DRT system is that the demand and supply match, which leads to a very efficient system. However, implementing a DRT system can be complicated and can have high investment costs. There are many forms of a DRT system. The first example is call-a-ride and its main concept is that the service allows you to call for a ride when demanded by the traveler, within a specified area (RTA, 2019). Call-a-ride transport is also called a dial-a-ride-transport system and can be used in various contexts. For example, in an area of Edinburgh, also known as Lothians, HCL Transport set up a charity called Handicabs (HCL Transport, 2020). This system is a charity which provides a door to door service for people with mobility limitations and who are unable to use the regular public transport systems. This service can help the users to use the mobility system and get out of the house. This could also be applied to the area of Schouwen-Duiveland. However, since only people with limited mobility can use this service, it will not solve the complete connectivity problem. Because it is a charity, sponsors should be found which gives that the investment is very high and the user group that it can help is small. Another DRT system that is a bit similar and can be used by everyone who wants to, is the Tele-Bus. This is a bus without a regular route or timetable, users can choose their starting and destination stop between several bus stops that are fixed (PTV, n.d.). In a municipality in Poland called Niepołomice, this was implemented and it was a success (Interreg Europe, 2018). Compared to the call-a-ride system this is more financially workable, since the user group is much larger and it is not a charity. However, this comes at the cost of the door-to-door service. The service offers transportation between bus stops, however travelers have to get themselves to and from the bus stops. The last example of DRT are electric, self-driving shuttle busses as tested within Stockholm (Krishnan, 2018). These self-driving shuttle busses were installed in a city to test if they could work with all kinds of modes functioning around them and if they are able to share information about the traffic around them. For this project they would be used in a slightly different way, since the problem area is rural. They could be used as a shared taxi service or replace the normal busses in the Tele-Bus system. The advantages of these self-driving shuttle busses are that they are green and that they do not require a bus driver. Such initiatives will show that the region is investing in new technologies and this might attract younger inhabitants (which is positive since the area has a problem with aging). However, they will not be available short-term since they are still in the process of being tested and they will have high investment costs.

Another potential smart technology is the smart hub. Smart hubs (or also called a multimodal nodes) “are places of encounter and connection of physical and non-physical networks, dynamic flows and changes’’ (Gasparovic et al., 2015). This implies that all kinds of transport modes come together in one location where efficient transits can take place. This will mean that the users will go to the smart hub and from there continue their journey in an efficient way. What makes the smart hub different from the current bus stations is that the smart hub will connect all kinds of modalities and will therefore be indirectly connected to much more (rural) places. The benefit of such a mobility center is that it can adapt by offering a perfect location to charge vehicles and to store the required fuel or energy to do so. Besides, with the help of new technologies, the smart hubs could be developed in a way that it can process travel data and then offer a transport supply based on the exact demand, making it easier to manage the peak hours. The first and last mile should be kept in mind when installing smart hubs, because users should manage to get to the smart hub.

Moreover, carpooling could also help the accessibility of the small island. People could carpool to say a bigger bus stop or bigger city from which they can continue their journey. A smart way of carpooling could be an app, where people can offer and ask for rides. People who are less mobile could share a ride, which makes sure that the elderly in the area are also able to get around which makes the system more accessible for all. However, the problem might occur that people are not willing to share their ride. Still, carpooling could be combined with the smart hub technology and solve the first and last mile problem there.

Another smart technology which could be implemented are shared vehicles. A shared vehicle is a vehicle that belongs to multiple households. ‘’Shared vehicles have all kinds of benefits for the user, community and environment and can even promote indirectly the use of public transport’’ (Rabbitt & Ghosh, 2013). This system would lead to fewer costs for the users, since they do not need a privately owned car, bike, or scooter anymore. A disadvantage of shared vehicles is that the investment costs are fairly high for the municipalities and/or province. Furthermore, the problem could arise that the shared vehicles clutter up at one or some locations and not at the locations where people would need them or that they would be needed just in the rush-hours which would make them less payable. If these shared vehicles would be combined with other smart technologies they could help to increase the connectivity of Schouwen-Duiveland.

Thus, looking at all these smart technologies which can improve the public transport of Schouwen-Duiveland, it can be concluded that a combination of some of these smart technologies could improve the system the most, since this would mean that for all types of users there is some form of public transport that can be appealing to them.

1.4 DESIGN OBJECTIVES

In general, mobility is essential to be able to go to school, work, stores, and other facilities or services. People on the island Schouwen-Duiveland are heavily car-dependent, however, there is still a need for public transport (Provincie Zeeland, 2018), also within Schouwen-Duiveland, as not all inhabitants are able to travel with a private vehicle. Examples of this are elderly people who cannot drive or cycle due to physical disability and younger people who need to travel larger distances to school. The improvement of public transport will hopefully also be a suitable alternative for the now ever increasing car usage.

The province also shares its ambition for the future in this report, which comes down to this: The goal is to make a futureproof mobility-system that is smarter, quicker, cleaner and makes use of the latest technological developments. Additional attention should be paid to the payability, consistency, freedom of choice and accessibility (Provincie Zeeland, 2018). In this report the following of these factors will be analyzed more into depth, because these are the most important design features for the user: quickness, payability, accessibility, and connectivity. The overview of the design objectives is shown in Table 3 below. The next step is to analyze the most important features of the smart solutions proposed in the literature review piece above, and link them to the design objectives, as has been done in Table 4.

Table 3 – Design Objectives

Design objective	Measurement indicators	Definition
Quickness	Travel distance (min) Travel speed (km/h)	The degree of improvement of the travel time between location A and B.
Payability	Profit Implementation cost User cost	Initial costs should be able to be earned back, otherwise it is not attractive to investors.
Accessibility	Weights Travel Time Threshold	A village is accessible if people are offered the possibility to travel to and from the village within an acceptable amount of time
Connectivity	Concept of permeability	Direct routes between locations A and B make the system more efficient

Table 4 – Analysis of proposed smart technologies

Smart technology	Pro's	Con's
DRT-Dial-a-ride	Quickness Accessibility Connectivity	Payability
DRT-Tele-bus	Quickness Payability Connectivity	Accessibility
DRT-Self-riding shuttle bus	Quickness Accessibility Connectivity	Payability
Smart hub	Quickness Payability Accessibility Connectivity	
Carpooling	Payability Accessibility	Quickness Connectivity
Shared vehicles	Payability Quickness Connectivity	Accessibility

The DRT services could be beneficial when looking at the quickness, accessibility, and connectivity. However this is dependent on the specific design of the system. For example, when the accessibility is high, many villages are connected, however this may come at the cost of the quickness as more villages are included in the system. Therefore, such trade-offs need to be examined actively. The payability of DRT is quite high, as it is an intensive form of public transport with high investment costs.

DRT, carpooling, and shared vehicles can all be implemented in combination with smart hubs to solve the first and last mile problem of travelers. Carpooling and shared vehicles are less convenient than DRT, since these options make the traveler reliant on a co-traveler. A public transport service has to meet certain standards and requirements that the mentioned co-traveler does not.

Having said this, the technologies that are chosen to tackle the public transportation problem of Schouwen-Duiveland is a combination of smart hubs and DRT. The DRT mode with Self-Riding Shuttle Busses seems the best option. This is somewhat futuristic and the current implication may not be self-driving, but our aim is to eventually implement this when possible due to the lower costs. For now, the solution that will be worked with is a combination of smart hubs and tele-buses.

The solution will be analyzed by means of the conceptual framework that will be introduced in chapter 2. Three possible scenarios will be investigated; a conservative, balanced, and progressive scenario. In chapter 3 the results will be published and in chapter 4 the results will be processed, leading to a conclusion, discussion, and recommendations.

2. CONCEPTUAL FRAMEWORK

2.1 RESEARCH OUTLINE

In this chapter, the research approach will be explained and the design for improvement will be introduced. Before every element is explained thoroughly in detail, this paragraph will discuss the outline of the remainder of the chapter. An overview can be found in Figure 4. First of all, the requirements for the future design are discussed. It is important to know the relevant boundaries and constraints, in order to propose a feasible solution. Furthermore, all assumptions are given, as a model cannot take into account all kinds of variables. Three scenarios are being introduced that will help to analyze the proposed solutions. Next, all measures that estimate the outcome of the design are being treated. This includes all variables, data and mathematical formulations that will be used in order to be able to do measurements. In the design part, the improvement suggestion is given and all variables discussed in the instrument part are connected by a conceptual model. Lastly, in chapter 3, the values of the design objectives will be determined with the variables which will make it possible to estimate the consequences of the design.

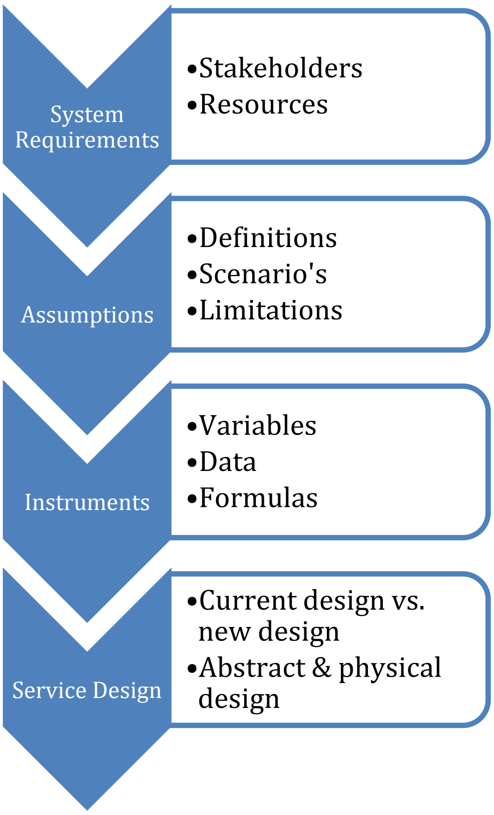


Figure 4 – Research Outline

2.2 SYSTEM REQUIREMENTS

2.2.1 STAKEHOLDER ANALYSIS

In order to find a fitting solution for the problem it is important to know which stakeholders will be involved in the process. By mapping the power and interest of the different actors it becomes clear which stakeholders can be approached for their power, and which stakeholders should be kept in mind throughout the process, because of their interest. The relevant stakeholders are the province, municipalities, city planners, commercial public transport operators, non-commercial public transport operators, start-ups (which are the new upcoming smart/shared mobility businesses), local people, visitors, secondary businesses (which are companies that benefit from a better mobility in the rural areas, but cannot contribute to this improvement), and lastly the traveler organization. In Figure 5, a power-interest diagram can be found, giving a visual representation of the stakeholders and their positions. An explanation for the position of these actors within the matrix can be found in Appendix C.

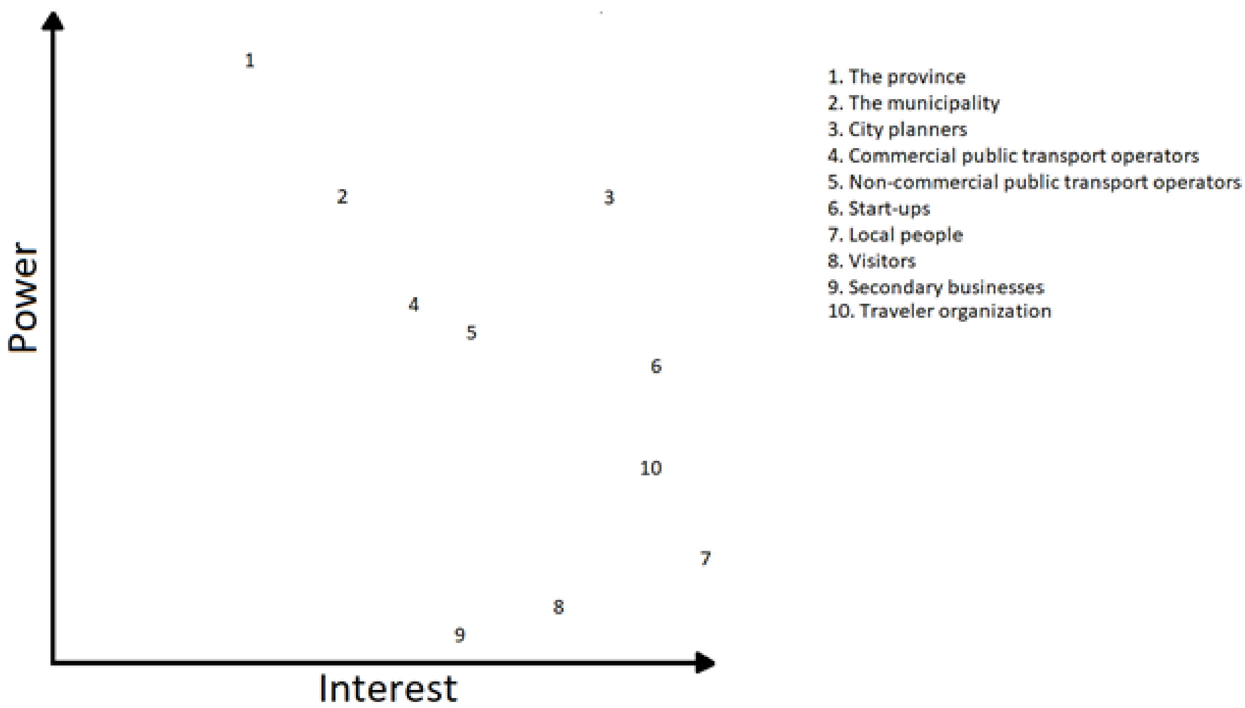


Figure 5 - Power-Interest Diagram

2.2.2 RESOURCES

For the Tele-busses system some common requirements are needed. These requirements contain different categories ranging from vehicles to infrastructure. Examples are busses, staff, and a road network. Most of these already exist and can be easily integrated into the new system. However, also some additional resources are necessary for a successful system. The proposed solution includes a small set of smart hubs that will be placed on strategic locations throughout Schouwen-Duiveland. To find these locations there will be looked to convenient road network nodes and the distance to surrounding villages. To place the smart hubs, clear areas at the proposed locations are needed that provide enough room for the stops, busses, and parking spots.

Besides this, new technologies will be implemented that need to be developed first. For the DRT system it is important that the provider enables a travel app, a smartphone application, which plans out the first- and last-mile transportation of the trip. This app should make it easy for travelers to reach their location by combining the demand and supply for every location at every time of the day. It is important that the app is accessible and simple, as there will also be a large, elderly audience, who might encounter trouble with this.

When the system is implemented, it is essential to keep revising all aspects of the system to prevent problems. In addition to this, obtaining and processing the feedback of the travelers is important to ensure a problem-free travel experience.

2.3 ASSUMPTIONS AND SCENARIOS

2.3.1 DEFINITIONS

Before creating and testing the model, it is important to define the different aspects of the model and make sure that the model measures the right variables. Examining the definition related to the design indicators will give further insights about the measurements, as the meaning of the variables is clearly stated. In Table 5, all variables are defined according to the most suitable definition found online. Measurement indicators derived from these definitions will be explained within paragraph 2.4.

Table 5 - Definitions

Term	Definition
Trip	A planned movement between two locations (start and finish) which has a distance of more than 50 meters.
Travel time	The duration of a trip calculated at the start of the trip
Travel distance	The distance between the start and end point of the trip calculated at the start of trip
Travel costs	Amount of money the user has to pay in order to travel between the two locations, calculated at the start of the trip
Accessibility	The degree to which an environment is accessible to as many people as possible
Connectivity	The density of connections within mobility networks, and the directness of links
Transfer	Change between vehicles within one trip
Smart hub	In this place of encounter, all kinds of mobility modes come together in an efficient and connected way where

2.3.2 Assumptions

The future travel behavior of inhabitants cannot be forecasted in detail as there are a lot of unknown factors that influence the travel activities of the user. However, the effect of the design must be measured to identify whether it is successful or not. To do so, scenarios are created, which are based on both the current travel behavior of the inhabitants and assumptions regarding the new design. Implementing these scenarios into a model makes it possible to compare the design with the current situation to measure the effect of the design. As not every aspect of the design can be known, assumptions are made which increase the forecasting abilities of the model. The assumptions are described in Table 6.

Table 6 - Assumptions

Term	Assumption
Trip	Start and finish of a route will be at the stops of the public transport system.
Travel Distance	The route between the smart hubs will be based on the shortest route.
Travel Distance	The route for the first and last mile, travelled with the Tele-bus, will be based on the shortest route between start/finish and the smart hub. Every extra stop between the start/finish location and the smart hub will multiply the shortest route with x1,5.
Travel speed	The average speed from the matrix will be used for the new design in order to calculate a new time schedule.
Travel time	Based on travel speed divided by travel distance.
Travel costs	Based on the ticket price of Connexxion for costs per minute, which is 0,18 euro/minute, and the travel time of time schedule.

Based on these assumptions, four types of trips can be distinguished: (1) traveling between rural villages within the region, (2) traveling to a smart hub within the region, (3) travelling to a smart hub within another region and (4) travelling to a rural village within another region. These different types will be examined in the model as different scenarios, which means that there will be four different scenarios.

2.3.3 Scenario's

In order to measure the effect of the new design, different scenarios are used within the model. These scenarios are based on combinations of the structure of the network system and the type of infrastructure, which differ between the scenarios. Changes in both the structure of the transport network system and/or the type of infrastructure will be guided by changing values within the variables based on assumptions. Within the model, changing the values will change the outcome for the different design objectives. Three scenarios are formed based on different existing or possible combinations. These different scenarios result in different levels, which will be compared to measure the effect of the design proposal. The levels are called the conservative, balanced and progressive level and will be explained below. Besides this, the model can measure additional factors that influence the effectiveness of the design proposal. This could give insights on how to implement the design which will be useful when making policy recommendations.

CONSERVATIVE LEVEL

The first scenario is called the conservative level. As the name already suggests, the conservative level consists of the current transport network system, which is based on the bus lines as they are today. The travel distance is therefore based on the current kilometers driven by the bus. Besides, the type of infrastructure used within this level is also traditional. This means that the travel speed is based on the type of vehicle in combination with the type of road that the vehicle uses. An example of this level is the current public transport system of Schouwen-Duiveland. For this reason, the results from the design objectives of this level will be used as the baseline measurements. In this way, the effectiveness of certain design aspects can be measured, as the results of the design objective increase or decrease from these baseline values.

The following value assumptions are used within the conservative level:

- Travel speed of DRT system: 30 km/h (Hensher et al., 2008)
- Travel speed of bus between smart hubs: 50 km/h (Hensher et al., 2008)
- Waiting time: 7 minutes

BALANCED LEVEL

The second scenario is called the balanced level. This level is a combination of a new transport system network and the current available type of infrastructure. By introducing the Demand Responsive Transport (DRT) system in combination with the smart hubs and the fast connections between each other, new routes are formed. As the routes become more efficient, the travel distance should become shorter. As this connected design is a ‘smart’ system, the different bus lines will be aligned within the smart hubs. This will result in a shorter waiting time as the transfers become more aligned. This level, however, is still not optimal as only the realistic changes are included. For this level this means that the type of infrastructure stays the same. Busses will drive on the normal road to get from location A to B. Therefore, the speed of both the DRT system and the busses driving between the Smart Hubs will stay the same.

The following value assumptions are used within the balanced level:

- Travel speed of DRT system: 30 km/h
- Travel speed of bus between smart hubs: 50 km/h
- Waiting time: 3 minutes

PROGRESSIVE LEVEL

The last scenario is called the progressive level. Maybe this level seems unrealistic for now, but it is important to include future perspectives as well to keep options for development open. New designs must not only be efficient within the present time, but they must also effectively fulfill the needs of the users in the future. In order to test whether the design is futureproof, the progressive level includes both the new transport system network and a new type of infrastructure. These new types of infrastructure could benefit the transport system network by allowing for instance busses to drive on special bus lanes. This would increase the travel speed of the busses driving between the smart hubs. These improvements of the infrastructure can allow the DRT-system to become faster. Also, the use of faster and/or self-driving vehicles can be an area for improvement.

The following value assumptions are used within the progressive level:

- Travel speed of DRT system: 50 km/h
- Travel speed of bus between Smart Hubs: 80 km/h
- Waiting time: 3 minutes

2.3.4 Limitations

Making assumptions makes it possible to do a data analysis. However, it would be better to quantify the assumptions as this would increase the predictive quality of the model. Also within this model, there are a few of such limitations, related to assumptions that are worth mentioning. The biggest limitation of this model is the lack of quantified trip orientation data. Knowing the exact trip orientation and distribution of the island could have helped with finding the most suitable transportation mode, as every trip has an optimal transport mode to travel with. Now the model makes use of general travel orientations which lack details about type of transport mode and cause of traveling. Besides, the dataset does not include the exact costs of the public transport system. Instead, the travel costs are based on the average amount of money the users pay per minute while using the public transport facilities. It would be better to implement the price per kilometer as time related pricing is sensitive to delays such as congestion and accidents.

2.4 VARIABLES, DATA AND MATHEMATICAL FORMULATIONS

In order to measure whether the solution design is successful, there needs to be a data analysis in the present state and the new state. This needs to be compared in order to say meaningful things about the design. In this report, the design objectives will be seen as guidelines to measure the current and new situation. As can be found in part 1.4 of this report, the design objectives are set to quickness, payability, accessibility, and connectivity. Within Table 3, all variables are presented with their measurement indicators. The design objectives are calculated eventually from data in an Excel matrix, which can be found in the additional file that comes with this report. The data in the Excel matrix is made first hand by implementing data from different sources into the matrix. These sources can be found per variable within the table. The matrix shows different variables for every village to each of the other villages. The different variables are combined within multiple formulas which calculate the values for the design objectives. In this way, changing one value of a variable influences all data values. This is necessary to create the different scenarios explained earlier and compare the different outcomes. The matrix is provided in a separate Excel file because the size did not fit properly in an appendix.

Table 7 – Data sources

Variable	Source
Travel speed	Bus rapid transit systems: a comparative assessment. (Hensher et al., 2008)
Travel distance (current/new)	Trip Planner within Google Maps
Euclidean distance	Google Eart
Travel time current system	Trip Planner within Google Maps
Travel time new system	Travel speed new * travel distance new * new waiting time
Ticket price current system	Tijdskaartjes Connexxion (Connexxion, n.d.) Price trip = price/minute * travel time current system
Ticket price new system	Tijdskaartjes Connexxion (Connexxion, n.d.) Price trip = price/minute * travel time new system
Weights for Accessibility	Displayed within the matrix, tab: “Weights”
Travel Time Threshold	Trip Planner in Google Maps

2.4.1 Quickness

Measuring the quickness of the different scenarios is done by calculating the travel time for each scenario. The variable travel time is expressed in minutes and based on the combination of travel speed and travel distance. The matrix for the new situation however, is rather tricky to make because of the demand responsive transport (DRT). The problem is that the travel times can vary a lot depending on the demand of that particular time. More specifically, there are a lot of different routes that the Tele-bus can drive. For example, a smart hub (SH) with villages A, B, and C can serve village A with a direct route to the smart hub, but there might be demand in village B as well which means that the route will go from SH→ A→ B→ SH. This means that a route can be shorter than normal, but also as long as before, or even longer. The hard part is to construct a mathematical formula for this average travel time to and from the smart hub. To decide this with mathematical formulas a lot of exact data is needed about the amount and distribution of demand per village. This data is not found to be available for the current situation, and even if it was, in the new situation the demand is expected to rise which makes the data outdated. In order to avoid this problem, the new travel distances within the new network system are calculated by taking the direct route from location X to location Y. This means that within the matrix no extended stops are made within the DRT-system and that the Tele-bus only drives directly between one village and the smart hub. As a route can make use of two different types of connections, the connection from village to smart hub with the Tele-bus and the connection between two smart hubs, two speeds are assumed. The first speed v1 is the speed for the DRT system, which is set to 30 km/h in our model. The second speed v2 is the speed for the busses that drive between the smart hubs, which is set to 50 km/h in our model. These speeds were assumed based on research on bus rapid transits (Hensher et al., 2008)

2.4.2 Connectivity

In order to measure connectivity, the concept of permeability will be used (Melia, 2012). This concept is often used to measure the connectivity for different types of travel mode, as each travel mode could have their own road layout. In the case of this study, there is a car and bus road system. In comparison, a bus network will always include multiple stops and therefore it has to take a detour in some cases. For this reason, a disadvantage will appear in the form of extra travel cost (time, money etc.). However, within Schouwen-Duiveland these travel modes make use of the same infrastructure and only drive other routes. Therefore, no comparison is needed between the car and bus road system, but this concept can still be used to measure the influence of the new PT system by analyzing the difference in connectivity between the current and the new design. To measure this, the travel distance from location A to B driven by the bus will be divided by the Euclidean distance between location A and B. In mathematical form this will be as follows:

$$P_{ij} = \frac{D_{ij}}{E_{ij}}$$

Where Pij is the permeability of the trip going from village i to village j. This is computed by dividing the travel distance Dij by the Euclidean distance Eij. This factor will be computed for both the old system and the new system.

2.4.3 Accessibility

In order to measure accessibility, the cumulative opportunity model will be used (Boisjoly et al., 2017). This model bases the accessibility of the village (i) on whether or not one village lies within the travel

$$A_i = \sum_j W_j \bullet f(C_{ij})$$

time threshold of another village (j). When lying within the travel time threshold, the jobs and facilities of one village (j) will be available for the other village (i), which causes people to travel between the villages. Higher accessibility values are therefore preferred, as higher accessibility means that more villages lie within the travel time threshold range of that village. The accessibility is measured by using the following formula:

Where the weight Wj is based on the number of inhabitants of the villages, number of jobs and of facilities (think of a secondary school or a hospital and tourism). f(Cij) is an impedance function on the travel cost. This travel cost Cij exists of the travel time from village i to village j. For the impedance function a negative exponential function is used. This function shows whether a village is in a specific travel time threshold (b), which is important as only the jobs and facilities located within the specific travel time threshold will be labeled as accessible. The value of this travel time threshold is 30 minutes as cars travel in approximately 30 minutes from one side of the island to the other side of the island. This means that almost all villages on the island can be reached by car within 30 minutes. The public transport system must match these number in order to prevent the users switching from public transport to car:

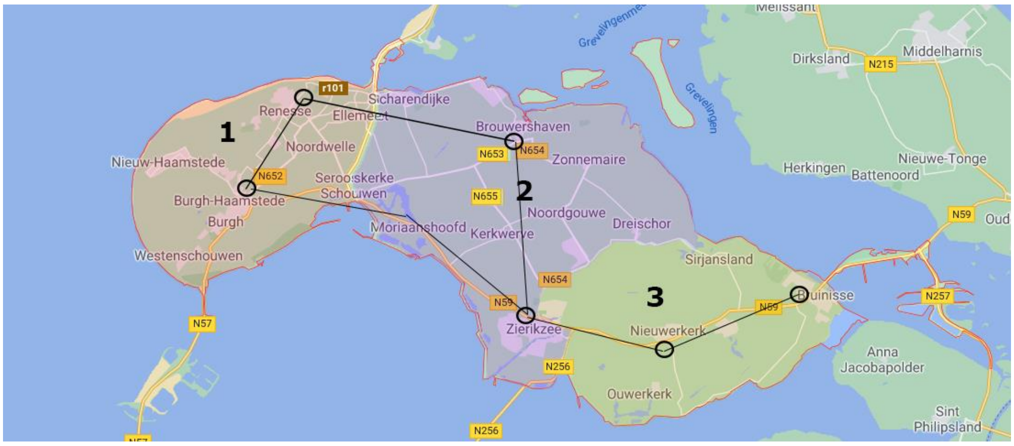
$$f\left(C_{ij}\right) = 0 \text{ } if \text{ } C_{ij} > b$$
$$f\left(C_{ij}\right) = 1 \text{ } if \text{ } C_{ij} \leq b$$

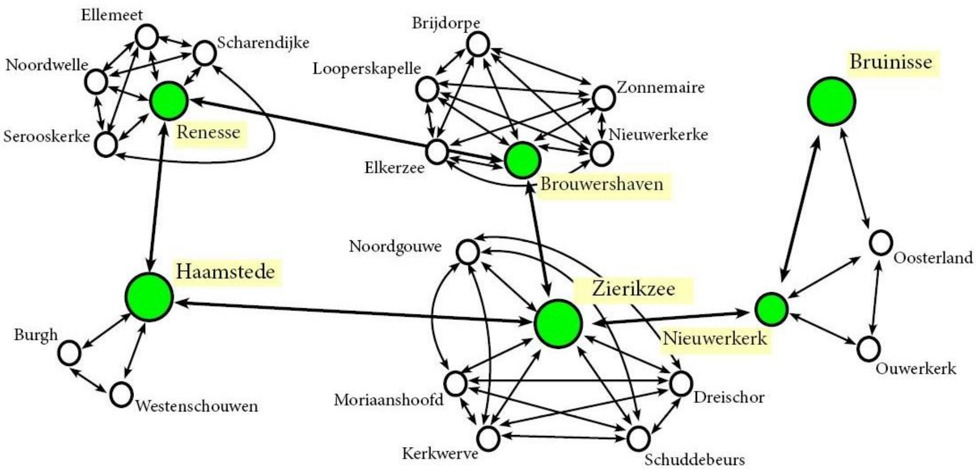
2.5 MOBILITY SERVICE DESIGN

The accessibility and connectivity of Schouwen-Duiveland are poor, which has been shown in the previous chapter. Multiple smart technologies were investigated and compared supported by the design objectives chosen. The design that resulted from this is a combination of two systems, namely smart hubs and a form of DRT called the tele-bus. Recall from chapter 1.3 that these technologies are new, innovative, adaptive and manageable by suitable assumptions thus smart. In Figure 6, the chosen locations of the smart hubs can be seen. The island will be split into three regions, where each region will have one or two smart hubs and every smart hub will have a tele-bus system operating in the region. The connection the smart hub has with the surrounding villages is provided by the Tele-bus network which uses a DRT-system to arrange the demand and supply between the different villages and the smart hub. This is an effective way as the demand coming from each village is low. Centralizing the different demands from the villages could make the system profitable as the demand supply ratio becomes more satisfying for the public transport provider and the users themselves. Instead of multiple buses of different villages driving from one region to another, the demand will be clustered per region and will travel as one demand towards another region. In this way, fast, efficient and regular bus connections can be created between the smart hubs. This is suggested to be an improvement relative to the current system as the new system works according to the demand of the users.

Moreover, the concept of smart hubs is a smart solution for clustering the demand within one region. Different types of transportation modes can come together within a smart hub which makes it possible for people to use both private and public transport towards a smart hub. It can for instance provide enough electrical posts for both electric cars and electric buses. According to the literature, the locations of these smart hubs within Schouwen-Duiveland are based on the size of the locations and the transportation orientation of the users. Therefore, the smart hubs will be located in Burgh-Haamstede, Renesse, Brouwershaven, Zierikzee, Nieuwerkerk, and Bruinisse as these locations are the most attractive locations within the region.

The users will be able to travel within the region and to the smart hub with these tele-bus services. They will plan their trip with an extension of their regular travel app, which will automatically make sure that there is a bus that will bring the user from the desired origin to the smart hub or the other way around. The user will pay with their regular OV-chip card or pay by debit card, like in the regular busses at the moment. The bus will be adapted to the demand of the users, which means that the bus does not have to make a complete circle like within the current network, see the difference between Figure 3 and Figure 7. Also, if the demand is always high around certain times, more buses could be implemented around these times. This will lead to a more efficient and faster bus line, since the demand and supply match due to the DRT. In Figure 7, one can observe that the number of connections of a village to other locations has increased immensely, which suggests that the accessibility and the connectivity of the rural areas increase.





3. IMPLEMENTATION RESULTS

3.1 RESULTS SCENARIOS

In order to analyze all the results, the matrix has been adjusted for each of the three scenarios. This matrix contains all the data needed to analyze each scenario on the four design aspects. In this subsection, the results of the three scenarios will be discussed. Each of these scenarios will have its own strengths and weaknesses compared to one another and based on these, the design can be assessed. An overview of all results regarding the design objectives travel time, accessibility and connectivity can be seen in Table 8 and Table 9, which will be explained within the different paragraphs.

Table 8 – Results per scenario

Design objectives	Conservative level	Balanced level	Progressive level
Quickness	Mean: 36.9 Standard Deviation: 22.4	Mean: 34.8 Standard Deviation: 16	Mean: 22.9 Standard Deviation: 10.9
Payability	Mean: €6,46 Standard Deviation: €4,03	Mean: €6,26 Standard Deviation: €2,88	Mean: €4,12* Standard Deviation: €1,98*
Accessibility	Mean: 68,304 Standard Deviation: 574	Mean: 80,651 Standard Deviation: 633	Mean: 121,735 Standard Deviation: 696
Connectivity	Mean: 2.69	Mean: 2.75	Mean: -

3.1.1 CONSERVATIVE LEVEL

In the conservative scenario, the situation of the public transport system on Schouwen-Duiveland is the same as the current state and this is why the results of this scenario will be used as the baseline measurements. This system runs according to the current bus schedule, which does not satisfy the needs of the user at the moment. Therefore, the current values for quickness, accessibility and connectivity will be labeled as insufficient. An average trip on Schouwen-Duiveland takes 36.9 minutes, which has a standard deviation of 22.4 minutes. The accessibility shows a value of 68,304 with a standard deviation of 574. The concept of permeability was used to calculate the efficiency of the route which is used to investigate the connectivity. This value was 2.69, which means that the route is more than 2.5 times as long as the Euclidean route. Of course, the Euclidean route is not possible to drive, which means that the connectivity can never be 1. However, 2.69 represented an undesired detour, which could be improved. Since this scenario is the same as the current situation the cost will be very minimal and thus optimal in that sense for the payability.

3.1.2 BALANCED LEVEL

In the balanced scenario, the current infrastructure is extended with the smart hubs and the tele-bus system. For the travel distances this means the distance from bus-stop to smart hub and/or to bus-stop will change. The new values for travel distances are, according to the travel distance of a car, using the existing infrastructure. This gave an average travel time of a trip of 34.8 with a standard deviation of 16. This means that the average did decline (-5.7%) but not significantly. On the other side, the standard deviation of the data did decrease (-28%). This means that (assuming normality) the probability that a travel time of a trip lies closer to the average is higher as in the conservative setting. Within the system this means that there are less outliers, which can be seen as something positive as remote villages seem to be better connected with the system. Looking at the accessibility, the same improvement is visible within the results. The accessibility increased by +18.1% and most of these improvements are related to accessibility of rural villages. The connectivity, however, did increase (by 2.2%). Despite the fact that it is a significant increase, this new value suggests that the travel distance within the new system has become longer. For this scenario there will be a new system and thus also investment cost, however the infrastructure stays the same and the bus stops and buses will still be used. This implies that the investment costs will be low and therefore they could be subsidized by the government. The user cost will stay the same.

3.1.3 Progressive level

The progressive scenario is an extension of the balanced level, where it is assumed that the infrastructure will also be improved such that the travel speeds of the buses increase. This can be done by, for example, special bus lanes around traffic lanes, special bus highways where they are allowed to drive a bit faster, short cuts to the closest highway or a more efficient DRT system. In this scenario, the travel time decreased by -37.9% compared to the conservative scenario. This is a significant improvement of the system. Also, the standard deviation of the travel time shows a significant decrease of -51%, which indicates that the number of outliers has decreased. The accessibility increased by +78.2% compared to the conservative level. Many rural villages now fall within the travel time threshold of more distant areas as the connections have been improved. However, the payability of this scenario is not very good since the investment cost will be significantly high. This is because not only a new public transport system will be needed, but also a new extensive infrastructure. This might result in a higher ticket price which could lead to less users of the new system (which is the opposite of what is being aimed for).

3.2 RESULTS DESIGN OBJECTIVES

3.2.1 Quickness

Quickness is one of the most important design objectives, as this will directly influence the way of how the service is perceived. It is measured in travel time (minutes). Within the model, the travel time of the scenarios was influenced by the travel distance, the travel speed and the waiting time of the system. These three variables differ between the three scenarios and therefore the value of quickness differs between the different scenarios. The travel time is directly dependent upon these three variables. As the matrix calculates travel time of each trip based on these variables. It is therefore also not strange that each scenario the quickness increased.

With each scenario, the travel distance decreased, travel speed increased, and the waiting time decreased. This logically means that the quickness is improved, and this was also seen in the results by a decrease in average travel time. The value of quickness seems to benefit most from the increased travel speed. Looking at the different scenarios, the balanced level only shows an improvement of 5,7% caused by new waiting time and new travel distance whereas the progressive level shows an increase of 37,9% caused by only a new travel speed.

In general, it can be said that the design objective ‘quickness’ improves with each scenario. The waiting time has a medium effect on this improvement, as this shows in the difference in travel time between scenario 1 and 2. The difference between these scenarios is only a reduction of 4 minutes on waiting time, this translates into an improvement of 2.1. When comparing this against an improvement of 11.9 with an improvement of 30 km/h on travel speed between smart hubs. Therefore, the travel speed has a high impact on quickness.

The other two variables, travel distance and waiting time, show no evidence for being significant. This being said, the fact that travel distance within the progressive level could not be measured could possibly make it significant, but this is not expected to be the case. Moreover, as expected, the new design did not improve the quickness of all villages. Even in the progressive scenario, five villages show an increased travel time for 40% or more of the in- and outgoing trips. These villages are Noordwelle, Serooskerke, Kerkwerve, Noordgouwe, and Scharendijke. No further research has been done to discover why these villages show on average an increased travel time, but it is suspected that the locations of the smart hubs did not work in favor of these locations. Future research could determine whether this is the case and how the positioning of the smart hubs could improve the travel time for all villages.

3.2.2 Accessibility

Accessibility showed a high correlation with travel time. This is completely understandable as the accessibility is measured with the use of travel time threshold. As the travel time decreased within the scenarios, the accessibility increased as a result. This is because more villages met the requirement of having a travel time below the travel time threshold to be accessible. Especially longer distances have increased their accessibility, which indicates that the smart hubs increase the accessibility of trips between regions. However, this effect is only visible within the progressive level, as the increased travel times for short distances in the balanced level overpower the decreased travel times for long distances. Moreover, the correlation between accessibility and travel time is also the reason that the travel speed significantly influences the accessibility values. These results can be interpreted from table 9 where the changes for both the scenarios are displayed. The percentages show how many villages have an increased, stayed equal or decreased accessibility value compared to the baselines.

As mentioned earlier, not all villages seem to have an increase in the accessibility value within the balanced level, with Noordwelle, Serooskerke, Kerkwerve and Noordgouwe as the main problem areas. These villages are located near each other on the island. This may indicate that the positions of the smart hubs are not placed correctly. This mainly has also to do with the fact that villages on the west side of the island are out of the 30 minute travel time threshold from the villages on the east side. Based on the age distribution given in the first paragraph of this report and more data on trip generation, the weights were computed for the formula of the cumulative opportunity model. These weights are in the form of trips. The table with this data can be found in Appendix D.

Table 9 – Change in Accessibility value regarding the baseline per scenario

Scenario	Change
Balanced level	Increased: 13%
	Equal: 70%
	Decreased: 17%
Progressive level	Increased: 40%
	Equal: 56%
	Decreased: 4%

3.2.3 Connectivity

As stated before, the connectivity is based on the travel distance of the network system. After calculating the travel distances for the new network system, an increase in travel distance was stated. This increase became also visible in the connectivity values, since the connectivity from the balanced level was higher than the connectivity value of the conservative level. Looking at the value differences per village, the data shows that the overall increase of the travel distance is largely caused by the increased travel distance of the incoming and outgoing trips of Ellemeet, Noordwelle, Serooskerke and Scharendijke. These villages were well connected within the old model. However, within the new model, these villages are divided over two different regions. This causes the travel distance to increase, as they must travel a detour within the new system.

There is no difference in connectivity within the longer distance trips, suggesting that for larger distances the busses already use many of the provincial roads. The model could only further improve when new types of infrastructure would be implemented. Examples of this are special bus highways between the smart hubs which match the Euclidean distance as good as possible. This will improve the connectivity as it decreases the network distance/Euclidean distance ratio towards a value of 1.

3.2.4 PAYABILITY

Payability can be investigated from the point of view of two groups, the organizers and the users. However, as this design objective was properly integrated within the model due to lack of data, the more general findings are explained in this paragraph. The organizers and responsible actors of this project are the province and the municipality of Schouwen-Duiveland. For them, it is important that the investment costs and the expected profit or loss long term are acceptable. These quantities are very important to estimate before the project will start, because this will determine if the project will be launched at all. From the interview with Nathalie Goedhart-Leijnse from Schouwen-Duiveland Op De Weg, it became evident that the province is willing to help new projects with their costs during the first two years and after that with a maximum of 40% of the cost. Furthermore, an overview of the costs of all pilots/studies on 'Schouwen-Duiveland Op De Weg' was given, which can be found in Appendix E. In this overview there is one pilot (out of 16) about a sustainable transferium which is currently launched which has a cost price of €1.000.000. More importantly, €900.000 is funded by the municipality of Schouwen-Duiveland, which means that the municipality is interested in new mobility pilots and willing to fund them almost completely. The total amount of money that 'SD op de weg' needs to fund all these pilots/studies is €2.084.782. However, to estimate the costs of this project is quite hard since tele-buses and smart hubs are new technologies of the public transport sector. But, some numbers will be given that can give an impression.

First of all, the investment costs could be significant. In this design six smart hubs will be built and five tele-bus systems will be created. In (University of California, n.d.) it is stated that for building one mobility hub the construction cost will be $12 million (which include: 'six-bay bus plaza, a sculptural canopy, benches, a pick-up and drop-off zone, and landscaping') and the total project cost $16 million. This translates to approximately 10.2 million and 13.6 million euros respectively. In the case of Schouwen-Duiveland, it can be argued that the costs will be lower since at all some locations there is a bus stop. Furthermore, not at all locations there will be a six-bay bus plaza needed, which will again decrease the investment cost. In (CROW-KpVV, 2015) some investment costs in the Netherlands are stated, for example, an extra bus will cost about €36.000 per year, implementing the current technology in a normal bus costs between €10.000 and €14.000 and an information display at a bus stop costs between €5.000 and €10.000 per bus stop. However, one could also argue that the cost can be higher since a smart hub will also need, for example, an electric power system and software for the communication between smart hubs, busses and users. Thus, to make an estimation of the initial investment cost is very hard at this point of the research and with the knowledge of our research group.

Furthermore, the payability of the public transport system is also dependent on the demand, since the system will be more profitable if more people would use it. Therefore, it would be best if the cost of a single trip would not increase too much, because otherwise, some users might look into alternatives and less people will want to switch to public transport. The bus fare elasticities of demand are stated 'bus fare elasticity averages around -0.4 in the short run, -0.56 in the medium run and -1.0 in the long run' (Balcombe et al., 2004). This means that if the bus fare decreases the demand will increase on the long run with the same percentage. This could be used to make an estimation on what a price change could do. However, the new public transport system will improve, therefore the demand can also increase, the improvement elasticity of demand is hard to estimate since this is a new kind of system. Therefore, the change in demand and thus the estimated income is hard to estimate.

Finally, the user should be able to pay for the public transport system. In the province of Zeeland the price for a 15 minute ticket is €2.70 (Connexxion, n.d.) this means that 1 min of public transport costs € 0.18 multiplied by the travel time in the new and old case the travel costs are estimated. These results can be observed in the matrix under the tab “Price new” . However, whether or not the bus company will increase or decrease the price per minute is not known and thus final conclusions about the price cannot be made.

Thus, determining the payability of the new public transport system is very hard, because of the lack of data and knowledge is available. More details about how many people use the current system, profit, investment of the province and municipalities, state of locations of future smart hubs, state of busses, costs of technology in tele-busses and estimated changes in demand are needed to say more about the payability of the future system.

3.3 EQUITY

There are two different age groups on the island that heavily depend on public transport. Both (high school) students between the 12 and 24 years old and elderly people from the age of 65+ need public transport to travel within and between the regions of the island. Therefore, it is required that the accessibility for these target groups increases. For both groups the accessibility has been measured and they show the following results.

STUDENTS (AGE: 12-24 YEARS OLD)

The accessibility of public transport improves for students when the new design is introduced. In the case of the balanced level, the total accessibility value is 4443, which shows an increase of 32,6% regarding the conservative level. This improvement is similar to the overall accessibility improvement. Evaluating the villages individually, the same problem areas arise for this target group as within the overall accessibility measurements. However, for students it is most important that Zierikzee has a high accessibility for all villages, as this is where the only high school of Schouwen-Duiveland is located. The balanced level shows an increased accessibility for five villages, while only two villages show a decreased accessibility, which are Noordwelle and Serooskerke. These two villages, together with the other villages with insufficient accessibility towards Zierikzee, require additional attention to increase their connection with Zierikzee.

ELDERLY PEOPLE (AGE: 65+ YEARS OLD)

Elderly people have less restrictions towards accessibility as their trips have multiple destinations. However, it is important that all locations have good connections with medical posts. These are located in the bigger villages and fortunately the ones where smart hubs are also located. This creates extra pressure on the DRT-system to improve the accessibility between the rural villages and their nearby smart hub. Looking at the balanced level, there is almost no improvement for short distances compared to the conservative level. Also the progressive level shows no significant improvements for the short distance trips. Future research therefore needs to examine if a DRT-system is the best option for elderly people to travel with. On the other hand, the accessibility towards Zierikzee improves in both the balanced and progressive level which is also important as the only hospital on the island is located there.

4. CONCLUSION AND DISCUSSION

4.1 CONCLUSION

The public transport of Schouwen-Duiveland is currently experiencing accessibility and connectivity problems related to the rural villages on the island. The situation for the people living in these villages can be improved by implementing a new, smart public transport network, which combines the use of smart hubs with a DRT-system. The combination of these two technologies cause users to cluster their trips within the smart hubs when travelling longer distances. This improves the demand and supply ratio which is necessary for the system to be profitable. The new network shows improvements on various aspects, such as travel time, which cause the overall accessibility to improve. More trips from all over the island become reachable within the travel time threshold of 30 minutes, which shows that the new network is an effective solution. Moreover, due to the use of smart technologies, the system is able to decrease the waiting time. Looking at the future, the new system seems capable of handling the implementations of new infrastructures as long as busses are being allowed to increase their travel speed. Thereby the system has proven itself as future proof.

4.2 DISCUSSION

In the report, there are several things that might be a subject of discussion. These can be categorized into limitations, interpretations, implications, and future research.

4.2.1 LIMITATIONS

There are quite some uncertainties that came up during the research and execution of the investigation. This is largely due to research limitations and the assumptions that had to be made because of this. Firstly, a lot more research can be done into what the optimal layout of the proposed smart hub network is. The current proposal is based on logical interpretation of several sources like inhabitants, flow networks, and current infrastructure on the island. It comes down to the realization that this is not the only way to design it. Secondly, the data for the matrix is based on the data from several sources, which might cause irregularities. Also, the travel time for DRT is very hard to calculate, due to the bus having flexible routes. This is excluded in this research and a standard factor is used, which causes the calculation to be less accurate. Lastly, the design objective accessibility has been calculated in one way, while there exist many ways to calculate this. This can cause irregularities and might even cause the results of the report to be interpreted differently per person.

4.2.2 INTERPRETATIONS

The way in which the report is structured and how the research has been done and presented could raise some questions. The most pressing issues will be discussed below.

For starters, the goal of the report was to implement a new, smart system with the aim to decrease travel times. However, this might not be totally right, actually one might argue that it is especially needed to connect the more rural villages better instead of trying to increase the average. One might also argue that a solution in which some villages are worse off and others better cannot be accepted purely because the average is less. They might argue this is not ethical to favor certain villages in this.

One might also argue that different 'smart' solutions are better options than the ones chosen in the report. The report has chosen the solution based on four criteria, while one could argue that this should be far more elaborated.

4.2.3 IMPLICATIONS

The research done in the report can actually have an impact on the current structure of public transport on Schouwen-Duiveland. The goal is to spark the discussion about how public transportation of rural areas can be improved. Whether the solution proposed in this report is the best or not does not really matter for this. It would be great to see that this report can start such discussion and might lead to a bigger research that can actually cause a restructuring of public transport, or even OTHER smart initiatives, like vehicle sharing or scooter rentals.

4.2.4 Future research

As described above, a lot of further research can be done on the topic of improving connectivity and accessibility in rural areas. The most important issue might be to investigate other solutions, in this way each solution can be compared and ranked. for example, shared vehicles, self-driving taxis/buses or other forms of a DRT system. This way one can compare the results and choose the optimal one. Furthermore, if the decision would be made to implement the tele-buses and the smart hubs one should reinvestigate the locations of these smart hubs and bus stops. Besides, more research into the design of the network map is needed. In this way it can be optimized and the smart hubs will be in the best positions. Along with this, the travel times for the DRT needs further investigation. In general, more field research needs to be done to incorporate the voice of the inhabitants. After all, they are the ones using the solution.

4.3 POLICY RECOMMENDATIONS

The previous two subsections allow for some policy recommendations. In this report it was made clear that there is a mismatch between the demand and supply in the public transport on Schouwen-Duiveland. To solve this mismatch, one should make sure that firstly the supply matches the demand by implementing a demand responsive technology and secondly to cluster the demand such that the public transport can function more effectively. From the results it became evident that this could work, however the results are only prominent if the buses could drive higher speeds on average. This means that to obtain a true difference one would need, for example, fast lanes for buses and thus a better infrastructure.

The final recommendation to improve the public transport system of Schouwen-Duiveland is to get some more money available from the municipality to invest in smart solutions that will bring public transport to a new level. This way the imbalance between the supply and demand of public transport can be solved.

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6. APPENDICES

Appendix A

	Schouwen-Duiveland [1]	Netherlands
Male	49.5	49.7 [2]
Female	50.5	50.3 [2]
Age group 01-14 years	13.9	15.7 [3]
Age group 15-24 years	10.3	12.3 [3]
Age group 25-44 years	18.9	24.8 [3]
Age group 45-64 years	30	27.8 [3]
Age group 65+	26.9	19.4 [3]
Single-person households	33.4	36.8 [4]
Households with children	29.8	25.6 [4]
Households without children	36.7	27.7 [4]
Population density (per km2)	147	504 [5]
Cars per household	1.2	0.9 [6]
Distance to general practitioner (in kilomerters)	1.4	1.0 [7]
Distance to supermarket (in kilomerters)	1.3	0.9 [8]
Distance to daycare (in kilomerters)	1	0.9 [9]

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Appendix B

The file provided by this paper includes the matrices with the information about the distances, travel time, transfers and average speed of the trips that can be made in Schouwen-Duiveland with the public transport can be found. The different tabs show the variable that is calculated. The sources of the data are highlighted in Table 7.

Appendix C

It can be seen that the province and the municipality are above the public transport operators in terms of power, considering the fact that the operators have to meet the demands imposed by the province and municipalities, like for example emission goals. The city planners are on the same level as the municipality, however their interest is higher, as they only focus on the future city plan, including mobility, while the municipality has more matters to attempt. The public transport organizations have medium power, as they have their own regulations, but these also have to comply with the agreements made with the municipality and the province. The public transport organization can have a great influence on the accessibility of transportation and on the contentment of the user. Start-ups do not yet have a lot of power, but are interested in new forms of first and last mile transportation. TheIk biy can contribute to creating a smart mobility solution. The local people have a large interest, as it is their demand that is not aligned with the current supply. Visitors have interest in a good working mobility network, as it makes it easier for them to travel to rural areas, however they do not really have a say in the mobility development of Schouwen-Duiveland. The secondary businesses only benefit indirectly when their employees experience less travel time. Traveler organizations have a statutory right of advice, meaning they pass on the opinion and experience of travelers towards transport companies and governments, however their advice is not compulsory to follow.

APPENDIX D

Village	Inhabitants	Jobs	Secondary School students	Camping stays	T inhabitants	T jobs	T campings	PT Trips total per day
Renesse	1060	2457	0	3.508	2883	1130	14033	541
Ellemeet	360	0	0	409	979	0	1635	78
Noordwelle	310	46	0	1.146	843	21	4585	163
Serooskerke	270	0	0	77	734	0	309	31
Scharendijke	1095	0	0	409	2978	0	1635	138
Haamstede	3210	334	0	1.154	8731	154	4616	405
Burgh	740	0	0	1.154	2013	0	4616	199
Westerschouwen	240	0	0	1.154	653	0	4616	158
Zierikzee	11225	6449	845	77	30532	2967	309	3608
Kerkwerve	995	139	0	77	2706	64	309	92
Noordgouwe	315	390	0	77	857	179	309	40
Schuddebeurs	395	0	0	77	1074	0	309	42
Mondriaanshoofd	55	0	0	77	150	0	309	14
Dreischor	985	594	0	77	2679	273	309	98
Brouwershaven	1300	334	0	1.193	3536	154	4773	254
Looperskapelle	68	0	0	409	186	0	1635	55
Brijdorpe	68	0	0	77	186	0	309	15
Elkerzee	68	0	0	77	186	0	309	15
Zonnemaire	755	46	0	77	2054	21	309	72
Nieuwerkerk	2645	1038	0	77	7194	477	309	239
Ouwerkerk	600	0	0	77	1632	0	309	58
Oosterland	2690	0	0	77	7317	0	309	229
Bruinisse	3830	1242	0	1.006	10418	571	4023	450
Total	33280	13069		12.547	90522	6012	50186	6996
							146720	
Trip generation								
Average	2,72							
Student	3,07							
Work	0,46							
Tourism	4,00							
% PT use	3,00%							

APPENDIX E

Totaalomvang SD Op Weg & pilots 2019 / 2020	Pilot	Naam	Fase	Totaal nodig	Tekort	Verwachte bijdragen	Bijdragen partners: Gemeente Schouwen-Duiveland	Provincie Zeeland	Zeeuwland	New Mobility Foundation	Windfonds Krammer	AgriSnellaad	Lokale inbreng uren	Opbrengst verhuur	Lokaal Bedrijfsleven	Stichting Renesse
1 Organisatie		SD Op Weg organisatie	*2 (realisatie)*	€ 92.500	€ 92.500	€ -	€ -	€ -		€ -						
A. Duurzame Mobiliteit	#1	Uitrol elektrische laadpalen	*0 (onderzoek)*	€ 2.500	€ -	€ 2.500	€ 2.500									
	#2	Pilot Autonoom rijden	*0 (onderzoek)*	€ 10.000	€ -	€ 10.000		€ 10.000								
	#3	Duurzaam mobiliteitspunt Transferium	*1 (opstart)*	€ 1.000.000	€ -	€ 1.000.000	€ 900.000							€ 100.000		
B. Zakelijke Mobiliteit	#4	Elektrificeren gemeentelijke voertuigen	*0 (onderzoek)*	€ 100.000	€ -	€ 100.000	€ 90.000							€ 10.000		
	#5	Deelauto's gemeentehuis	*0 (onderzoek)*	€ 10.000	€ -	€ 10.000	€ 2.500							€ 5.000	€ 2.500,00	
C. Toeristische Mobiliteit	#6	Aanbesteding (duurzaam) natransport Transferium	*2 (realisatie)*	€ 284.200	€ -8.000	€ 292.200	€ 292.200									
	#7	Agenda Toerisme, thema Toeristische Mobiliteit	*1 (opstart)*	€ 157.200	€ 7.200	€ 150.000	€ 75.000	€ 75.000								
D. Sociale Mobiliteit	#8	Schoolbus Zonnemaire	*2 (realisatie)*	€ 120.000	€ -	€ 40.000	€ 40.000									
	#9	Elektrische taxi Duinen van Haamstede	*2 (realisatie)*	€ 11.000	€ 3.000	€ 8.000	€ 3.000	€ 2.000						€ 3.000		
	#10 t/m #14	Schouwen-Duiveland Deelt: opstartkosten deelautopilots	*1 (opstart)*	€ 130.320												
	#10	Deelauto's Brouwershaven (incl. deelauto Zeeuwland)	*1 (opstart)*	€ 70.301	€ -689	€ 70.990	€ 4.000		€ 14.400			€ 5.000	€ 10.000	€ -		
	#11	Deelauto's Bruinisse	*1 (opstart)*	€ 70.301	€ -539	€ 70.840					€ 22.580	€ 10.000				
	#12	Deelauto's Renesse (incl. deelauto Zeeuwland)	*0 (opstart)*	€ 1.200	€ 1.200	€ -										
	#13	Deelauto Zierikzee (incl. deelauto Zeeuwland)	*0 (onderzoek)*	€ 23.260	€ 8.910	€ 14.350	€ 900		€ 8.450			€ 5.000				
	#14	Deelauto Kerkwerve	*0 (onderzoek)*	€ 2.000	€ 2.000	€ -										
	#15	Scholierenvervoer & pilot elektrische	*0 (onderzoek)*	€ -	€ -	€ -										
	#16	Pilot Integratie doelgroepenvervoer & Openbaar Vervoer	*0 (onderzoek)*	€ -	€ -	€ -										
Totaal				€ 2.084.782	€ 391.752	€ 1.693.030	€ 1.410.100	€ 87.000	€ 22.850	€ -	€ 22.580	€ 20.000	€ 10.000	€ 118.000	€ 2.500	€ -