VOLUME
2

Advances in
Transport Policy and Planning

Population Loss: The Role of Transportation and Other Issues

SERIAL EDITOR
Bert van Wee

VOLUME EDITORS
Rachel S. Franklin
Eveline S. van Leeuwen
Antonio Paez

VOLUME TWO

ADVANCES IN TRANSPORT POLICY AND PLANNING

Population Loss: The Role of Transportation and Other Issues

This page intentionally left blank

VOLUME TWO

ADVANCES IN TRANSPORT POLICY AND PLANNING

Population Loss: The Role of Transportation and Other Issues

Edited by

RACHEL S. FRANKLIN
Newcastle University,
Newcastle upon Tyne, United Kingdom

EVELINE S. VAN LEEUWEN
Wageningen University & Research,
Wageningen, The Netherlands

ANTONIO PAEZ
McMaster University,
Hamilton, ON, Canada

ELSEVIER

ACADEMIC PRESS
An imprint of Elsevier

Academic Press is an imprint of Elsevier
50 Hampshire Street, 5th Floor, Cambridge, MA 02139, United States
525 B Street, Suite 1650, San Diego, CA 92101, United States
The Boulevard, Langford Lane, Kidlington, Oxford OX5 1GB, United Kingdom
125 London Wall, London, EC2Y 5AS, United Kingdom

First edition 2018

ISBN: 978-0-12-815454-0
ISSN: 2543-0009

Publisher: Zoe Kruze
Acquisition Editor: Sam Mahfoudh
Editorial Project Manager: Shellie Bryant
Production Project Manager: James Selvam
Cover Designer: Alan Studholme

Typeset by SPi Global, India

CHAPTER THREE

The potential of a Mobility-as-a-Service platform in a depopulating area in The Netherlands: An exploration of small and big data

Karst T. Geurs[a,*], Konstantinos Gkiotsalitis[a], Tiago Fioreze[a], Gideon Visser[b], Mettina Veenstra[c]

[a]University of Twente, Enschede, The Netherlands
[b]HAN University of Applied Sciences, Arnhem, The Netherlands
[c]Saxion University of Applied Sciences, Enschede, The Netherlands
*Corresponding author: e-mail address: k.t.geurs@utwente.nl

Contents

Abstract

This chapter describes a case study examining the potential of a community-driven Mobility-as-a-Service (MaaS) platform in a rural and depopulating area in the Netherlands. The aim of the 5-year project is to examine if a MaaS platform can be an effective and efficient solution to improve accessibility and liveability of rural areas. The potential for a MaaS is examined by addressing the current mobility patterns and mobility and accessibility barriers. We use a mixed method approach using a combination of small data (primary data) and big data (secondary data).

Keywords: Mobility-as-a-Service, Rural area

Advances in Transport Policy and Planning, Volume 2
ISSN 2543-0009
https://doi.org/10.1016/bs.atpp.2018.09.001

1. Introduction

International experiences on providing public transport services for rural and sparsely populated areas are similar around the world. An ageing population in low-density and dispersed areas, combined with strong competition from private cars, make it difficult to operate profitable commercial public transport services which also meet the accessibility needs of different user groups (ITF, 2015). The need for public transport services to tackle problems related to accessibility and mobility is undisputable (Currie, 2010). In the Netherlands, in particular in rural areas, public transport has become more expensive and increasingly unprofitable due to demographic changes (i.e., aging), higher fuel costs and the increasing use of cars and e-bikes, leading to the need for high(er) subsidies (Dutch Ministry of Transport, 2010). Providing efficient and high-quality public transport alternatives at a fair price is a major challenge for the government and is often hampered by financial pressure. According to Brake and Nelson (2007), in an ideal world, public transport would be as convenient and flexible as private transport, suggesting that public transport services would be completely demand responsive and that travelers could use a service whenever desired. Such level of flexibility or convenience is infrequently achieved by conventional public transport services. Cervero (1997) states that conventional public transport cannot compete with the private car, because it is, among other things, unable to serve spontaneous travel. What stands out is that it is not so much the travel speed that is considered important, but the ability to travel spontaneously; when, where and as often as desired (Daniels and Mulley, 2010).

To tackle the problem of the inflexibility of conventional public transport, a myriad of alternative transport services have been developed where service provision is influenced by the demand and needs of the users, for example, through flexible routing or demand responsive scheduling (Mageean et al., 2013; Nelson and Phonphitakchai, 2012). The development of ICT has given opportunities to develop new mobility solutions in rural areas, including ride sharing platforms, demand responsive public transport systems, and combinations of public and private transport and with personalized flexible routes and schedules. More recently, Mobility as a Service (MaaS) has been presented a new and more comprehensive mobility concept, delivering users' transport needs through a single interface of a service provider. In several cities around the globe MaaS systems have been piloted since 2012.

This chapter aims to examine the potential demand for a MaaS deployment in a rural and depopulating area in the Netherlands by using multiple data sources. First, a survey is conducted to examine user preferences, satisfaction with the degree to which existing transport modes offer a sufficient level of access to important destinations and the willingness of car travelers to share a ride. Second, smart card and cellular data are used to examine the spatial and temporal variation in travel patterns. To the authors' knowledge, this is the first study to examine the potential demand of a MaaS platform in a rural area prior to its implementation using small and big data. The study is part of the 5-year research project Netmobil in which a community-driven MaaS platform is developed, tested and implemented. The aim of the Netmobil project is to examine if a MaaS platform can be an effective and efficient solution to improve the accessibility and liveability of rural areas.

The remainder of the chapter is structured as follows. Section 2 presents a literature review on mobility solutions in rural areas. Section 3 describes the case study area. Section 4 describes the results of the survey and analysis of smart card and mobile phone data. Section 5 presents the conclusions and describes the next steps to be taken within the framework of the Netmobil project.

2. Mobility solutions for rural areas: Literature review

The problems of insufficient public transport supply and high car dependency in rural areas are not new. Many different demand responsive mobility services have been developed and applied in practice around the globe. Early solutions in the Netherlands involve community-based public transport, in which local citizens collaborate with public transport operators in providing mini-bus transport services on fixed routes and timetables. In some regions in the Netherlands, some of these systems have existed for over 30 years. The provision of these traditional forms of neighborhood-based bus services is however becoming increasingly problematic. Budgets for public transport are decreasing and will decrease further in the coming years, costs are increasing and the operations are inefficient (demand is high during peak-hours and very low in off-peak hours). In short, this form of community-driven public transport with fixed routes and schedules is likely to prove not to be viable. Also, other public transport services in rural areas such as taxi systems are expensive (de Jong et al., 2011) and demand responsive transport (DRT) services are not, in most cases, financially viable (e.g., see Papanikolaou et al., 2017; Ryley et al., 2014; Wang et al., 2015).

In recent years, ICT developments have stimulated the development of ride-sharing platforms. Many of these platforms are small scale. All modern ride-sharing tools use some kind of information technology (internet site, an app, sms, email or a combination of these) but differ in the degree of automatic matching, payment solutions and target groups. Currently, there seem to be many operational ride sharing platforms in rural communities in developed countries. However, not all ride sharing platforms are successful. An evaluation of six trials of ride sharing platforms in rural areas in Sweden and Germany showed that throughout the 6 months implementation phase all platforms struggled with a low number of participants (50 active users or less) and consequently few shared rides (Alvanger, 2014). Issues that need to be addressed are a lack of user involvement and incentives for joining a ride-sharing initiative and the balance between the price a passenger pays and what the driver gets.

Recently, the concept of Mobility-as-a-Service (MaaS) is receiving increasing attention both in academic literature and in policy making. Jittrapirom et al. (2017) describe the main elements of a MaaS platform in their review paper. To summarize, a MaaS platform offers several transport options (public transport, taxi, car-sharing, ride-sharing, bike-sharing, car-rental) in one platform with integrated ticket and payment in monthly payments and/or "pay-as-you-go." A MaaS ecosystem is built on interactions between different groups of actors through a digital platform: users (e.g., private customer or business customer), suppliers of transport services and platform owners. MaaS is a user-centric paradigm as it seeks to offer a transport solution that is best from the customer's perspective via a multimodal trip planning feature. It also involves customization to modify the offered service option in accordance to the customer's preferences.

Jittrapirom et al. (2017) and Kamargianni et al. (2016) give an overview of operational MaaS systems and pilot projects in Europe (Austria, Finland, Sweden, Germany, France and the Netherlands) and the United States. These overviews show that current operational platforms focus on integrating car sharing, bike sharing and public transport and none of these systems target rural areas. In rural areas, the business case for MaaS will differ from urban areas, with a stronger focus on ride sharing and car sharing and less on public transport services. In the Netherlands, advanced integration schemes are designed for business travelers (such as Mobility Mixx, NS-Business Card) which provide a smart card to access a variety of modes across the country including shared modes, public transport and taxis. To date, however, these systems do not include ride sharing as a mobility option. In the

Netherlands several MaaS pilots are currently being planned. MaaS is a main transport policy focus at the national and regional level. For example, the Dutch Ministry of Infrastructure and Water management plans to experiment with seven MaaS pilots in 2019. One of these pilots is to be conducted in a rural area, aiming to contribute to more efficient transport in rural areas.

This overview shows that there is little experience with MaaS applications in rural areas. From the literature it is clear that many ride sharing platforms in rural areas struggle to capture a sufficient number of participants in rural and scarcely populated areas. Issues are a lack of community involvement, incentives for joining a ride-sharing initiative and the financial and non-financial benefits for passengers and drivers. Currently there is no evidence from the literature showing how much potential a MaaS platform, offering a variety of transport options in a single platform, has to overcome the issues and barriers that many ride sharing platforms have experienced.

3. Case study area

The study area for the development and implementation of the Netmobil MaaS platform is the "Achterhoek" region, in the eastern part of the Netherlands belonging to the Province of Gelderland. The Netmobil MaaS platform is being designed as a community-driven platform and integrates bike sharing, car sharing, ride sharing, taxi and public transport services in a single platform. The Netmobil project started early 2018 and will finish in 2021.

The Achterhoek region is a predominantly rural region, with much open space, forests and farms, with approximately 400,000 inhabitants. It is one of the regions in the Netherlands with a projected population decline in the next decades. In comparison with 2018, the population in that region is projected to decline by 5% in 2030 and by 9% in 2040 (PBL/CBS, 2016). Moreover, the population structure is also changing. Young, highly educated people and families are leaving so that the remaining population consists of relatively many elderly people. Facilities such as shops, sports clubs, schools and care facilities are becoming increasingly difficult to maintain. On the other hand, social capital is high within villages and the region is moving from a traditional rural and industrial region toward a region with new innovative industries, making it a dynamic region. Therefore, the Achterhoek should not be looked at as just a region in decline (Atzema et al., 2017).

The first application of the Netmobil MaaS platform will be conducted in one of the municipalities in the Achterhoek called Oost-Gelre (see Fig. 1),

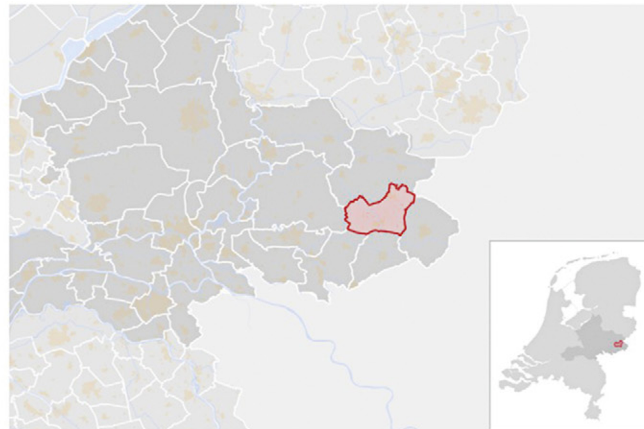

Fig. 1 The case study area in the Netherlands, location of towns and villages and zoning Source municipality boundaries: Statistics Netherlands/Topografische Dienst Kadaster, 2015.

in 2019. The municipality of Oost-Gelre has about 30,000 inhabitants and consists of two main cores: Groenlo (around 10,000 inhabitants) and Lichtenvoorde (about 13,000 inhabitants) and six villages of around 1000–2000 inhabitants (Harreveld, Lievelde, Mariënvelde, Vragender, Zieuwent and Zwolle). For the analysis in this chapter, the study area has been divided into four zones as shown in Fig. 1. The zoning is based on the spatial resolution of the mobile phone data used in the analysis (see Section 4). Zone 1 consists of the villages Harreveld, Mariënvelde, Zieuwent and its rural surroundings, about 4350 inhabitants altogether. Zone 2 consists of the city of Lichtenvoorde. Zone 3 consists of the villages Lievelde and Vragender, about 2500 inhabitants altogether. At last, zone 4 consists of the city of Groenlo and the small village of Zwolle.

The population in the municipality of Oost-Gelre is forecasted to decline by 6% by 2030 and 10% by 2040 (PBL/CBS, 2016). Public transport in the areas consists of one train station (located in a small village Lievelde in between Groenlo and Lichtenvoorde) connected to the network of traditional bus lines and scheduled minibuses ("buurtbus"). The minibuses are driven by volunteers and operate during working days with fixed routes and schedules between 7 am and 7 pm (and flexible stops) and in evenings and weekends with on-demand services (reservation 1 h in advance). In addition, a taxi-based public transport service is in operation, as in many low-density areas in the Netherlands, targeting residents such as school children who are not capable of traveling by regular public transport.

The municipality of Oost-Gelre was selected for several reasons. First, there was a local sense of urgency considering mobility and accessibility. Second, the local authority as the local community organized in a network active in six villages within the municipality considers the development of a MaaS platform an addition to local mobility and projects. Participation of the municipality and local communities is absolutely necessary to conduct a successful pilot. Both the municipality and local communities (especially a network of six small villages) showed their interest in the Netmobil project. Third, the municipality has a varied population and a variety of medium sized and small sized settlements which is suited for a Maas application.

4. Evaluating the potential for a mobility as a service

4.1 Survey setup and results

A revealed preference survey is conducted among residents over the age of 18 of the municipality using a mixed mode recruitment method. First, a pen-and-paper survey was distributed to 2000 residents, based on a random draw of the population. Second, participants were recruited for an online survey by using adds and Facebook posts. Third, fieldworkers have recruited respondents, focusing particularly on elderly people and younger people (in between 15 and 25 years of age). Responses were collected for 7 weeks from May 1st till June 17th, 2018. All responses were automatically recorded via the survey platform. Of the 1014 survey entries recorded, 862 were entitled to be further analyzed. The remaining 152 entries were discarded either because the participant did not answer any question or he or she reported to live outside the municipality of Oost-Gelre. The mixed mode recruitment method resulted in a good distribution of respondents by gender, age, household composition and education level compared to the population. More importantly, the survey sample is representative of the population of the municipality of Oost-Gelre, as illustrated in Fig. 2.

The survey comprised revealed preference questions on existing travel patterns (such as frequently visited locations), attitudes toward different transport modes (including ride sharing), satisfaction with the level of access specific destinations and level of capability to travel independently and use smartphone and internet. In addition to the survey, respondents were asked to download and use a smartphone app to allow a detailed analysis of travel

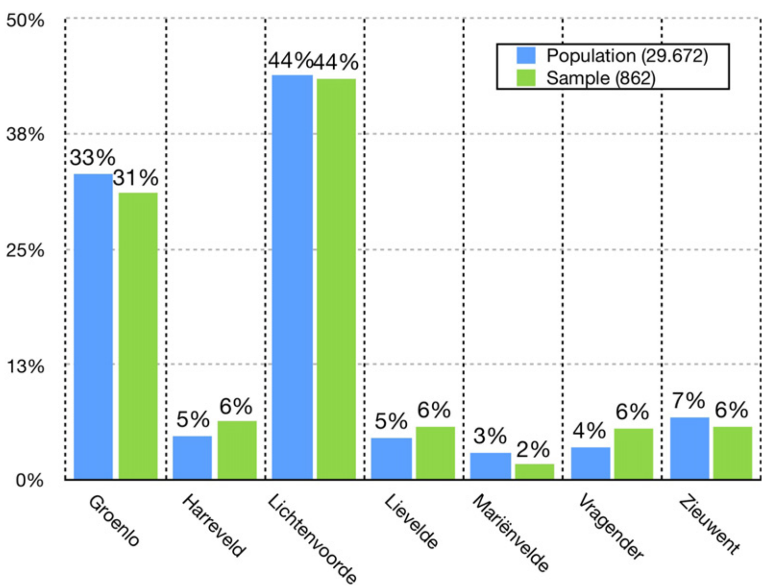

Fig. 2 Frequency distribution of survey respondents in comparison with the distribution of inhabitants in the municipality of Oost-Gelre.

patterns over a multi-week period. About 130 respondents participated and provided useful data.

The survey data are analyzed with SPSS Statistics (version 24) by using descriptive and inferential statistics techniques. The statistical approach is based on the distribution of responses with a margin of error of plus or minus 3 percentage points and a confidence interval of 95%. Moreover, we are particularly interested in finding out whether there is any association between some categorical variables of interest, such as the satisfaction of inhabitants of different zones with the level of accessibility and the current mobility services. In order to evaluate whether any relation exists, we use the Chi-square independence test (denoted by χ^2). If associated (using a significance level of 0.05), we subsequently employ Cramer's V (denoted by φ_c) to quantify how strong the relation is, i.e., how strong the two categorical variables are associated.

First, we examine how satisfied are the inhabitants of the considered zones based on the purpose of their travel. In general, the inhabitants of the municipality of Oost-Gelre are mostly satisfied with the accessibility of their destinations when performing fixed trips, but less satisfied when performing trips with low recurrency. In more detail, when analyzing the levels of satisfaction in the different zones of interest (see Fig. 3), significative differences are observed for some travel motives that do not have a fixed pattern.

We observed very weak ($\varphi_c < 0.15$) levels of significative association ($P < 0.05$) with respect to the zones of interest and how satisfied inhabitants are concerning accessibility for the following travel motives: *doing the daily grocery shopping, going out socially, and making a day trip.* The remaining travel motives did not show a significant association.

Residents in the rural areas (zones 1 and 3) are slightly more prone to be dissatisfied when doing groceries than the residents in the city areas (zones 2 and 4). Moreover, residents in zone 2 (Lichtenvoorde) are slightly more satisfied when going out socially than the rest. Finally, residents in zone 1 are more likely to be dissatisfied when making a day trip, whereas residents in zone 2 are more likely to be satisfied when doing so.

Independent of the zone of interest, the residents' level of dissatisfaction when traveling to school or other study locations is considerably higher when compared to the other travel destinations. Residents were not asked about which modes of transport they use for each travel motive, but it is very likely that most of them (especially students) use public transport (mostly bus) for that. Interestingly enough, students are entitled to travel for free

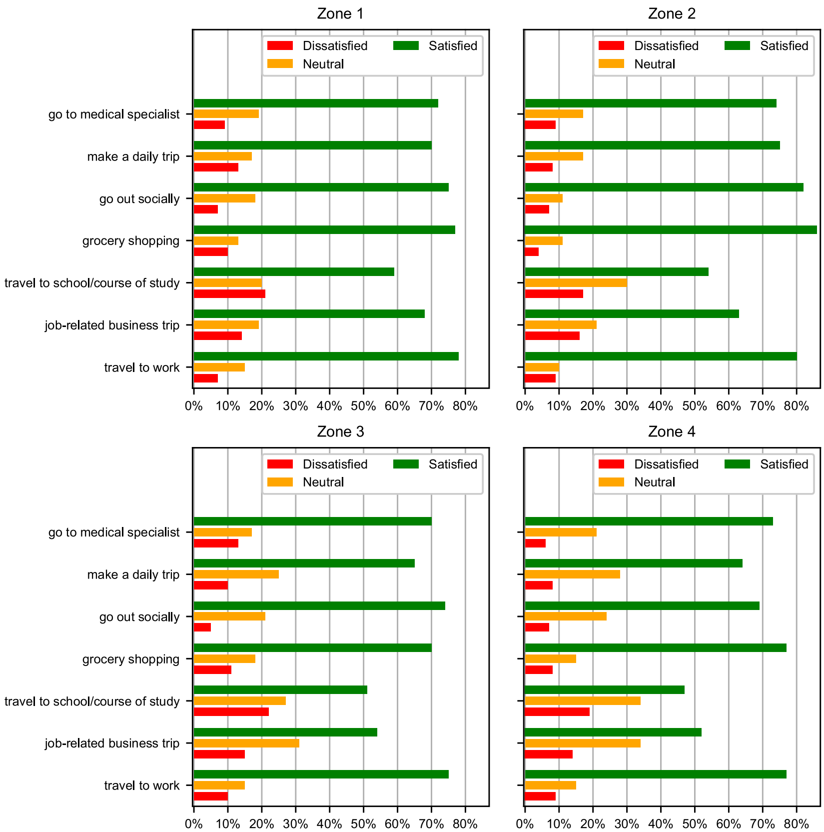

Fig. 3 The levels of satisfaction per travel motive in the four zones of interest.

(or with discount) on public transport to and from their school/course and, even so, their level of dissatisfaction is the highest.

After establishing a connection between the satisfaction of travelers and the trip destinations, we note that non-recurrent (infrequent) trips such as making a job-related business trip or a day trip exhibit the lowest satisfaction levels in all zones (after the education-related trips). These trips can potentially be accommodated by a MaaS platform; thus, later on, we will investigate the origin-destination pairs of infrequent trips with the use of detailed mobile phone data.

Except the activity type at the destination, another factor that can affect the satisfaction level of travelers is the mobility supply. For this, we analyze the modal split in the zones of interest to investigate if the mobility supply affects the level of dissatisfaction associated with the less frequent trips (such as grocery shopping, business trips and others that do not have a fixed destination like the home-to-work trips). In general, the frequency of car and bicycle use in the municipality of Oost-Gelre is higher than the other modes of transport, whereas taking the public transport occurs sporadically, at best (see Fig. 4 that presents the responses of the surveyed population).

As one might have expected, Fig. 4, which is based on the responses of the survey data, demonstrates a significantly higher frequency of almost daily use of car (as driver) in the sparcely populated areas (zones 1 and 3) when compared to the city areas (zones 2 and 4). Moreover, zone 3 has not only the highest frequency of almost daily use of car (as driver) but also the highest frequency of weekly ride sharing (i.e., use of car as passenger). This can be linked with another observation in our study. We observe that the frequency of sole car use goes hand in hand with the frequency of ride sharing, as seen in the weak level of association between frequency of car use (as driver) and frequency of car use (as passenger), $\chi^2(9)=78.69$, $P=0.000$ and $\varphi_c=0.176$ (Table 1).

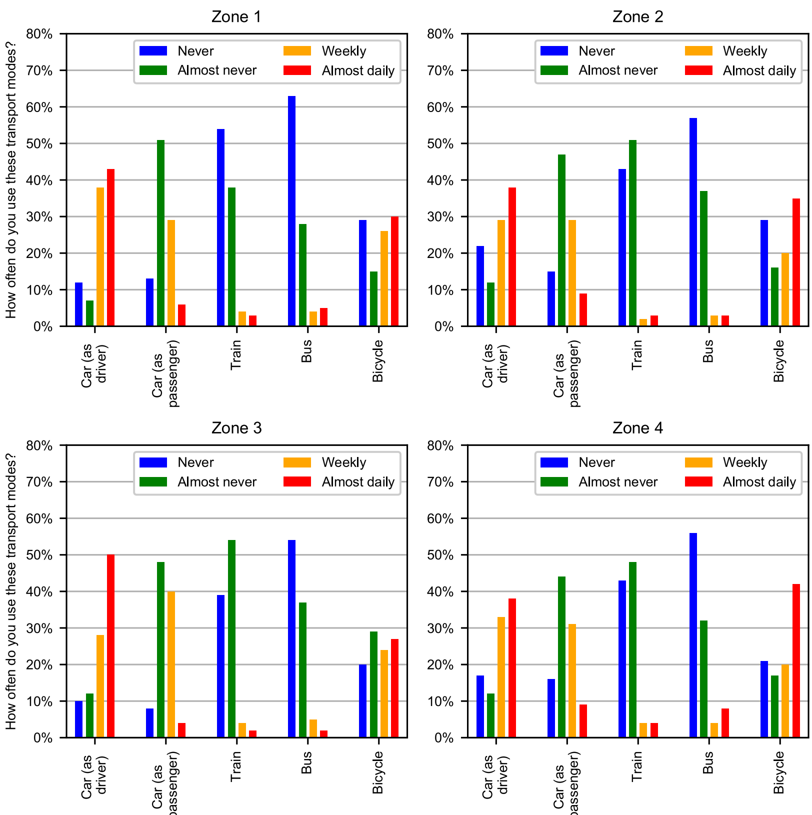

Fig. 4 Frequency of transport mode use per different zone of interest.

Table 1 Crosstabulation frequency of sole car use and ride sharing.
Ride sharing

	Never		Almost never		Weekly		Almost daily		Total	
Car (as driver)	**Count**	**% Within car as driver**	**Count**	**% Within car as driver**	**Count**	**% Within car as driver**	**Count**	**% Within car as driver**	**Count**	**% Within car as driver**
Never	22	13.7	76	47.2	51	31.7	12	7.5	161	100.0
Almost never	19	20.0	64	67.4	10	10.5	2	2.1	95	100.0
Weekly	41	15.8	111	42.9	104	40.2	3	1.2	259	100.0
Almost daily	34	10.3	138	41.9	106	32.2	51	15.5	329	100.0
Total	116	13.7	389	46.1	271	32.1	68	8.1	844	100.0

From the analysis of the survey data, one can observe a link between (a) the dissatisfaction of the mobility options of inhabitants of sparsely populated areas when conducting flexible trips with low recurrency and (b) the high levels of car use and ride sharing in those areas (zones 1 and 3). This topic requires further examination since it is interesting to see how the non-recurrent trips vary within the day and investigate whether they can justify the use of a MaaS by analyzing the more detailed data sets of the mobile phone data which provide information about the variation of infrequent trips in time and space.

Before proceeding to this analysis though, we examine the level of willingness to share a ride for inhabitants that are frequent car drivers and frequent car passengers using the responses of the survey data. Even if one would expect that car drivers and car passengers share the same thoughts on MaaS solutions, this is not the case.

The crosstabulation of Table 2 shows a very weak level of association between frequency of car use (as driver) and standing toward sharing a ride with strangers, $\chi^2(6) = 20.75$, $P = 0.002$ and $\varphi_c = 0.111$. This crosstabulation shows that if somebody drives a car almost daily, it is more probable that he or she will have a negative standing toward sharing a ride (with strangers).

However, when raising the same question to car passengers, we see the opposite answer. Indeed, a very weak level of association between frequency of car use (as passenger) and standing toward sharing a ride with strangers was

Table 2 Crosstabulation frequency of sole car use and sharing a ride with strangers.
Standing on sharing a ride with strangers

	(Very) negative		**Neutral**		**(Very) positive**		**Total**	
Car (as driver)	**Count**	**% Within car as driver**	**Count**	**% Within car as driver**	**Count**	**% Within car as driver**	**Count**	**% Within car as driver**
Never	73	47.7	61	39.9	19	12.4	153	100.0
Almost never	30	31.3	49	51.0	17	17.7	96	100.0
Weekly	115	44.1	89	34.1	57	21.8	261	100.0
Almost daily	158	48.2	99	30.2	71	21.6	328	100.0
Total	376	44.9	298	35.6	164	19.6	828	100.0

Table 3 Crosstabulation frequency of car users as passengers and sharing a ride with strangers.

Standing on sharing a ride with strangers

	(Very) negative		Neutral		(Very) positive		Total	
Car (as passenger)	**Count**	**% Within car as driver**	**Count**	**% Within car as driver**	**Count**	**% Within car as driver**	**Count**	**% Within car as driver**
Never	52	46.8	38	34.2	21	18.9	111	100.0
Almost never	186	48.1	135	34.9	66	17.1	387	100.0
Weekly	110	41.0	107	39.9	51	19.0	268	100.0
Almost daily	28	41.2	15	22.1	25	36.8	68	100.0
Total	376	45.1	295	35.4	163	19.5	834	100.0

observed, $\chi^2(6) = 18.69$, $P = 0.005$ and $\varphi_c = 0.106$ (Table 3). The contingency table shows that if somebody uses the car as passenger almost daily, it is more probable that he or she will have a positive attitude toward sharing a ride (with strangers).

The conclusion here is that frequent car drivers could potentially share a ride, but they are more likely not willing to do so. This conclusion comes as no surprise since offering a ride can be more complicated than taking one. Most likely the driver has to take another route that he is used to in order to pick up someone, which results in longer travel times.

4.2 Spatio-temporal variations of infrequent trips and public transport use

This section examines the spatio-temporal variation of trips in the study areas based on big data from smart cards and mobile phones to help us understand which origin-destination pairs and times of day have the highest potential for a MaaS service in Oost-Gelre.

For this, we use cellular data from mobile phones in combination with smart card data from buses and trains. Mobile phone data have the advantage that sampling bias is relatively low (because of large geographic coverage and high penetration of mobile phones) but have the disadvantage that the spatial resolution is fairly low; thus we had to merge a number of villages into the four larger zones. To perform a comparative analysis, we aggregate the national public transport smart card (OV chipkaart) data on the level of the four zones depicted in Fig. 1 to ensure that the public transport and the mobile phone data cover the same zones.

Detailed and anonymized smart card data have been made available by the Province of Gelderland, the regional public transport authority for the year 2016. The smart card data contain information of all tap-ins/tap-outs of passengers at the Achterhoek region, enabling the identification of the origin and destination stop for each trip. The total amount of analyzed smart card trips is 4,553,777 (on average, 12,476 trips per day).

From the public transport trips made in the Achterhoek region in 2016, 629,461 were performed[1] at the Oost-Gelre municipality (~13.82%). It should be noted here that two out of the six villages in Oost-Gelre (namely, Vragender and Zwolle) do not have any public transport stops. Table 4 and Fig. 5 present the origin-destination matrix of the smart card trips in Oost-Gelre (including the incoming and outgoing trips from the Achterhoek region) for March (note that we select March as the month of reference because we have mobile phone data from the same month). The key observations from Table 4 and Fig. 4 are:

1. The incoming and outgoing trips from other areas outside the Oost-Gelre municipality to the cities of Groenlo (zone 4) and Lichtenvoorde (zone 2) account for 62.5% of all public transport trips in Oost-Gelre. This indicates that public transport is not commonly used for trips inside Oost-Gelre;
2. Zone 1 has low interaction with the other three zones in Oost-Gelre and most public transport trips from zone 1 are from/to other areas in the Achterhoek region.

Table 4 Oost-Gelre's origin-destination matrix of all smart card trips in march (including the incoming and outgoing trips from other areas in the achterhoek region).

	Zone 1	Zone 2	Zone 3	Zone 4	Outside Oost-Gelre
Zone 1	0	65	75	63	763
Zone 2	87	98	3100	1554	6984
Zone 3	100	3526	36	3128	2085
Zone 4	80	1591	2735	448	12,074
Outside Oost-Gelre	844	6261	2155	12,199	0

[1] We assume that a trip is performed in Oost-Gelre if it is originated or attracted by a public transport stop in Oost-Gelre.

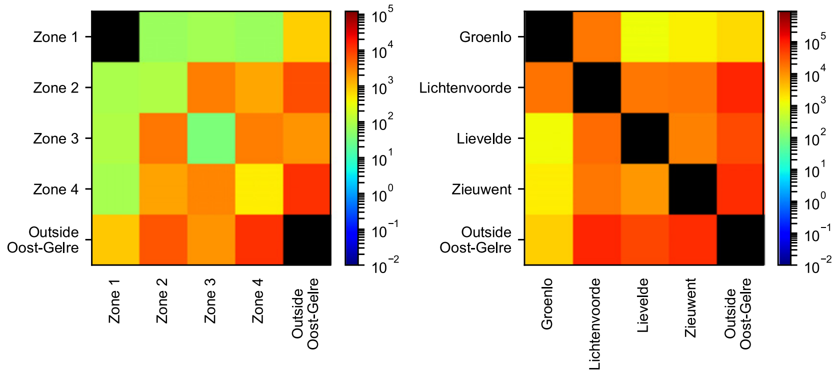

Fig. 5 Visualization of the origin-destination matrix of public transport trips (left) and the origin-destination matrix of mobile phone data trips (right).

Note also that the sum of all trips in Table 4 gives us the total number of public transport trips generated by and attracted from the four zones in Oost-Gelre. This sum is equal to 60,051 trips and is a reasonable number since the yearly number of trips in Oost-Gelre is 629,461 dictating that almost a 10th of the yearly trips are performed in March.

In addition to the smart card data, we analyze an anonymized and pre-processed origin-destination matrix of mobile phone data derived from Vodafone users, one of the largest mobile phone operators with a market share of about 30–40% in the Netherlands. The mobile phone data cover 1 month of data from March 1st to March 31st, 2018. Note that trips with an origin and destination at the same zone are not provided because of privacy reasons. When mobile phones are used to make calls, text messages or to send or receive data, signals are transmitted to a central computer. The Call Detail Records (CDR) have been preprocessed by a company to determine where mobile phones are located and how they move and translated into Origin-Destination data based on several decision rules (see Wismans et al., 2018 for a description of the methodology).

Using the origins and destinations[2] of all mobile phone trips in March, the origin-destination matrix of the trips in Oost-Gelre (including the incoming and outgoing trips from/to the Achterhoek region) is presented in Table 5 and Fig. 5. Given that the retrieved mobile phone trips do not represent the entirety of the trips in the region, the number of observed trips

[2] The mobile phone data indicate as a trip origin the area from which a traveler starts his/her journey and a trip destination the a place where someone stays for at least 30 min. OD-pairs with less than 16 trips per day are excluded from the data for privacy reasons.

Table 5 Oost-Gelre's origin-destination matrix of all trips derived from mobile phone data in March (including the incoming and outgoing trips from/to other areas in the Achterhoek region).

	Zone 1	Zone 2	Zone 3	Zone 4	Outside Oost-Gelre
Zone 1	0	17,404	1178	1581	2433
Zone 2	17,758	0	16,991	17,741	80,558
Zone 3	1271	20,881	0	13,298	40,318
Zone 4	1674	17,313	9168	0	71,772
Outside Oost-Gelre	2961	80,804	41,971	72,954	0

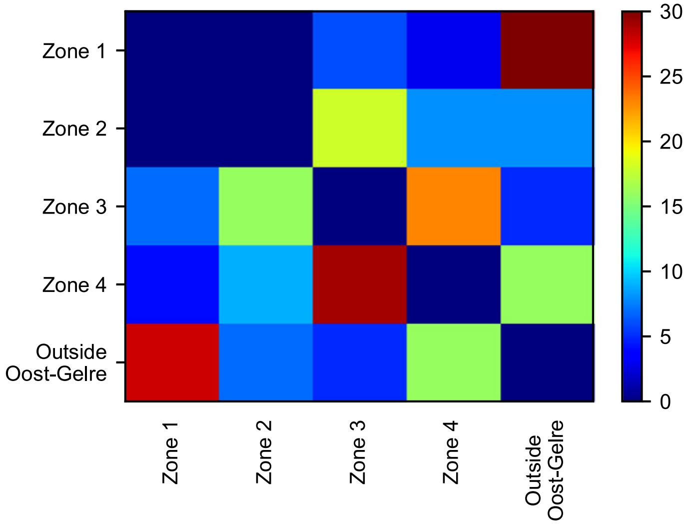

Fig. 6 Percentage (%) of public transport trips per origin-destination pair in Oost-Gelre.

has been expanded (using the Vodafone market share) to achieve the total amount of trips in the study area.

Investigating further the public transport use in different zones, we calculate the portion of public transport trips at each zone and present the results in Fig. 6. Note that the diagonal of the figure is always 0% because there is no mobile phone data availability for the intra-zonal trips. Notably, the percentage of public transport trips for each origin-destination pair is below 15% except the case of trips from zone 1 to other areas outside Oost-Gelre. Zone 1 is an interesting case because its inhabitants use public transport for traveling from and to other areas outside Oost-Gelre, but they do not use it for trips within the municipality. In contrast, inhabitants of zone 3 use public transport frequently to travel to zone 4 and vice versa. In summary, the public transport use for trips within the municipality is limited with percentages in the range of 0–10% (this is in line with the responses of the surveyed population which were presented in Fig. 4).

Continuing the analysis, we examine the spatio-temporal variations of the infrequent trips to explore the potential of a MaaS service that targets infrequent trips for which the survey respondents indicated a lower level of satisfaction. In the mobile phone data, there are two trip categorizations: (i) *infrequent trips* which are origin-destination trips that are conducted by a specific individual nine times or less per month and (ii) *frequent (regular) trips* which are trips performed more than 10 times per month by an individual. In addition, the temporal resolution of the mobile phone data is hourly (an origin-destination matrix can be provided for each hour of the day).

Let us consider two 1-h periods of the day, $I_j \neq I_k$, where each period I_j starts at hour $j \in \{0, 1, 2, \ldots, 23\}$ and ends 60 min later. Using the mobile phone data, for each hourly period I_j we can compute the origin-destination (OD) matrix of the infrequent trips, $\mathbf{O}^{I_j} = \{O_{rq}^{Ij}\}$, where r and q are the origin and destination zones of each OD pair and can take any value from the set $Q = \{\text{zone 1, zone 2, zone 3, zone 4}\}$. From this OD matrix, one can derive the probability of having an infrequent trip from origin r to destination $q \in Q$ within the time period I_j as:

$$P_{rq}^{I_j} = \frac{O_{rq}^{Ij}}{\sum_{r \in Q} \sum_{q \in Q} O_{rq}^{Ij}} \tag{1}$$

Computing this probability for all OD pairs indicates the spatial variation of infrequent trips within the time period I_j. This hourly matrix with the trip probabilities between all OD pairs, $\mathbf{P}^{I_j} = \{P_{rq}^{Ij}\}$, can be used for comparing the spatial distribution of trips for different time periods of the day, $I_j \neq I_k$. For this, one can employ a modified version of the Kullback-Leibler (KL) divergence (Kullback and Leibler, 1951) that indicates the difference between probability distributions. KL divergence is an asymmetric measure of the difference between two probability distributions and several modifications (i.e., Briët and Harremoës, 2009; Gkiotsalitis and Stathopoulos, 2016) can be used for transforming it into a symmetric one.

For ensuring a symmetric KL probability distance, where $\mathrm{KL}_{I_j, Ik} = \mathrm{KL}_{I_k, Ij}$, $\forall k, j \in \{0, 1, \ldots, 23\}$, we introduce the following formulation:

$$\mathrm{KL}_{I_j,I_k} = \frac{1}{|\mathrm{Q}|^2} \sum_{r \in \mathrm{Q}} \sum_{q \in \mathrm{Q}} \left| P_{rq}^{I_j} - P_{rq}^{I_k} \right|^2 \tag{2}$$

where $P_{rq}^{I_j}$ and $P_{rq}^{I_k}$ indicate the trip probabilities between all OD pairs for the time intervals I_j and I_k, respectively. The KL divergence matrix can be constructed by comparing the probability distance of the spatial distributions of trips for all hourly time periods of the day following Eq. (2). Obviously, this is a 24×24 symmetric matrix. For comparing the spatio-temporal variations of frequent and infrequent trips, we compute the KL divergence matrices for both the frequent and the infrequent trips in the mobile phone data and we present the results for a typical weekday in Fig. 7.

In Fig. 7, the symmetric KL divergence matrix starts from 6 am because there are no data for the first hours of the day. The figure shows that the spatial distribution of *infrequent* trips varies significantly from hour to hour. This demand cannot be easily accommodated by a fixed public transport service that operates in a schedule-basis.

Compared to the infrequent trips, the spatial variation of frequent trips exhibits a more stable behavior and there is a clear area (indicated with blue color) where the KL divergence is very small and the spatial distribution of trips remains almost unchanged. The time period of the day with the most similarities in terms of the spatial distribution of fixed trips is 1–4 pm. The spatial distribution of trips from 6 am until 10 am appears to be quite random and does not match the distribution of trips in other periods of the day. The same applies for trips after 4 pm.

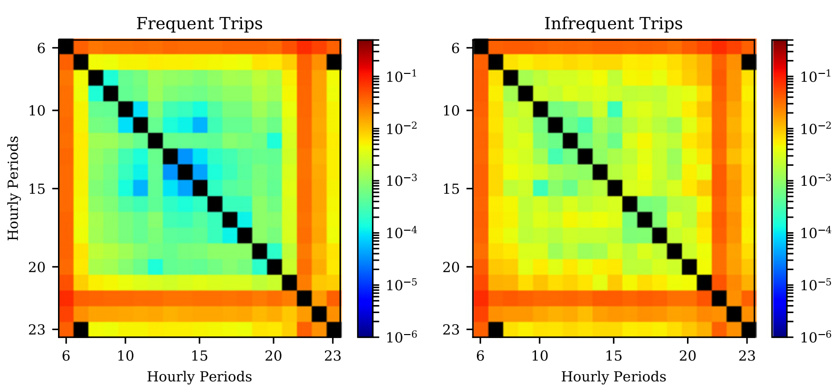

Fig. 7 Symmetric KL divergence matrices for both the frequent and infrequent trips for a typical weekday in March in the form of a 2D contour (plotted in logarithmic scale).

Table 6 Oost-Gelre's origin-destination matrix of all infrequent trips from 10 am to 9 pm for a typical weekday in March.

	Zone 1	Zone 2	Zone 3	Zone 4
Zone 1	0	273	0	0
Zone 2	297	0	296	318
Zone 3	30	409	0	281
Zone 4	38	332	149	0

Derived from the mobile phone data.

In contrast to the stability of frequent trips, the lack of (substantially) long time periods with mild spatial variations for the infrequent trips impedes the introduction of a fixed-schedule service (i.e., bus or train service) for accommodating them and reinforces the need to introduce more flexible mobility solutions. Focusing on infrequent trips, we examine the potential infrequent trip demand at each OD pair and we present the results for all infrequent trips from 10 am until 9 pm in Table 6.

Especially in zones 1 and 3 (which rely heavily on car use for trips within the municipality), there are 993 infrequent daily trips within Oost-Gelre that have a potential to be accommodated by a MaaS service.

5. Conclusions and further steps

In this chapter we used multiple data sources spanning from household surveys to smart card and cellular data to examine the potential of a MaaS platform in the municipality of Oost-Gelre, a rural and depopulating area in the Netherlands.

From the statistical analysis of the survey it can be concluded that inhabitants are generally satisfied with their accessibility and mobility options when conducting fixed, re-current trips (i.e., trips to/from work, etc.) even in sparsely populated areas with no public transport connections. This might be the result of residential self-selection processes where residents typically have access to a car and have a preference for car use and/or are capable of finding alternative mobility solutions for conducting their most common trips. Residents do show relatively high dissatisfaction levels for infrequent trips to varying destinations which are not fixed and study-related trips (i.e., trips to school). Infrequent trips with varying destinations (i.e., groceries, etc.) lead to a higher level of dissatisfaction in sparsely populated areas with less mobility options because, even if inhabitants of sparsely populated areas are able to organize well their fixed trips, the lack of alternative mobility options probably impacts the efficient planning of trips with no fixed destinations.

Furthermore, car drivers in the study area do not seem to be very willing to share rides. Frequent car passengers are more willing to adopt new mobility solutions. This is in line with the literature on ride sharing platforms in rural areas showing issues such as the need for community involvement, incentives for joining a ride-sharing initiative and financial and non-financial benefits for passengers and drivers.

Analysis of smart card and mobile phone data revealed that less than 5% of the respondents use public transport on a daily basis, and most of the public transport trips are to and from other areas in the Achterhoek region. The analysis of the spatio-temporal trip variation shows that infrequent trips exhibit a significant variation on the spatial distribution of trips across different times of the day (something that hampers the introduction of fixed-schedule services for accommodating infrequent trips).

The combination of analyses conducted in this chapter indicates that a MaaS platform in the study areas should target students and travelers who perform infrequent trips with activity types at the destination that span from making a day trip to business trips.

The study presented in this chapter is part of the Netmobil project which aims to iteratively develop and evaluate a MaaS system in the Achterhoek region. The outcomes of this study are used to identify the mobility challenges and problems different target groups in the Achterhoek experience. The next step is to evaluate these quantitative results by collecting additional qualitative data from citizens in the Achterhoek, as a starting point for an iterative co-design process of a MaaS system for the Achterhoek with potential end-users. With an emphasis on the involvement of the community in the development of a MaaS solution, we aim to address issues identified in the literature review such as lack of user involvement and lack of financial and non-financial benefits for participants.

A first pilot with the MaaS system in the municipality of Oost-Gelre will be conducted in 2019 and will allow us to study if the demand potential as indicated in this ex ante evaluation can be realized. A second pilot is planned for part of the years 2020 and 2021 with a version of the MaaS system that is improved based on the outcomes of the first pilot. In the final phase of the project, not only the quality of the mobility system will be assessed but also the usability of the system for the inhabitants of the municipality where the pilots have taken place. At the same time, final conclusions will be drawn on whether and how the system could be used permanently at the pilot location and possibly beyond.

References

Alvanger, K., 2014. Implementation of Ride Sharing. Final Report Project Mobile Together. Energy Agency for the Southeast Sweden.

Atzema, O., Hospers, G.J., Van Oort, P., Renooij, P., Teisman, G. & Tordoir, P. 2017. De Kracht van Oost Nederland. Een economisch-geografische analyse. Werkdocument. Regioplan/ESD/IHS/Atelier Tordoir: Amsterdam/Den Haag/Enschede/Nijmegen/Rotterdam. Available at: https://www.gelderland.nl/De-Kracht-van-Oost-Nederland-werkdocument

Brake, J., Nelson, J.D., 2007. A case study of flexible solutions to transport demand in a deregulated environment. J. Transp. Geogr. 15 (4), 262–273.

Briët, J., Harremoës, P., 2009. Properties of classical and quantum Jensen-Shannon divergence. Phys. Rev. A 79 (5), 052311.

Cervero, R., 1997. Paratransit in America: Redefining Mass Transportation. Praeger, Westport, USA.

Currie, G., 2010. Quantifying spatial gaps in public transport supply based on social needs. J. Transp. Geogr. 18, 31–41.

Daniels, R., Mulley, C., 2010. Overcoming barriers to implementing Flexible Transport Services in NSW. In: 33rd Australasian Transport Research Forum Conference. Institute of Transport Studies, Monash University, Canberra, Australia.

de Jong, W., Vogels, J., van Wijk, K., Cazemier, O., 2011. The key factors for providing successful public transport in low-density areas in the Netherlands. Res. Transp. Bus. Manag. 2 (0), 65–73.

Dutch Ministry of Transport, Public Works and Water Management, 2010. Public Transport in the Netherlands. Ministry of Transport, Public Works and Water Management, The Hague, the Netherlands.

Gkiotsalitis, K., Stathopoulos, A., 2016. Joint leisure travel optimization with user-generated data via perceived utility maximization. Trans. Res. C Emerg. Technol. 68, 532–548.

ITF, 2015. International Experiences on Public Transport Provision in Rural Areas. ITF, Paris.

Jittrapirom, P., Caiati, V., Feneri, A.-M., Ebrahimigharehbaghi, S., Alonso-González, M.J., Narayan, J., 2017. Mobility as a Service: a critical review of definitions, assessments of schemes, and key challenges. Urban Plan. 2 (2), 13–25.

Kamargianni, M., Li, W., Matyas, M., Schäfer, A., 2016. A critical review of new mobility services for urban transport. Trans. Res. Proc. 14, 3294–3303.

Kullback, S., Leibler, R.A., 1951. On information and sufficiency. Ann. Math. Statist. 22 (1), 79–86.

Mageean, J., Nelson, J.D., Wright, S., 2013. In: T. O. R. Group, (Ed.), Demand Responsive Transport: Responding to the Urban Bus Challenge. University of Newcastle upon Tyne, Newcastle upon Tyne, UK.

Nelson, J.D., Phonphitakchai, T., 2012. An evaluation of the user characteristics of an open access DRT service. Res. Transp. Econ. 34 (1), 54–65.

Papanikolaou, A., Basbas, S., Mintsis, G., Taxiltaris, C., 2017. A methodological framework for assessing the success of Demand Responsive Transport (DRT) services. Trans. Res. Proc. 24, 393–400.

PBL/CBS, 2016. Regionale bevolkings- en huishoudensprognose 2016–2040 [Regional Forecast of Population and Household Developments 2016–2040]. Netherlands Environmental Assessment Agency/Statistics Netherlands, The Hague.

Ryley, T.J., Stanley, P.A., Enoch, M.P., Zanni, A.M., Quddus, M.A., 2014. Investigating the contribution of Demand Responsive Transport to a sustainable local public transport system. Res. Transp. Econ. 48, 364–372.

Wang, C., Quddus, M., Enoch, M., Ryley, T., Davison, L., 2015. Exploring the propensity to travel by demand responsive transport in the rural area of Lincolnshire in England. Case Stud. Transp. Policy 3 (2), 129–136.
Wismans, L.J.J., Friso, K., Rijsdijk, J., de Graaf, S.W., Keij, J., 2018. Improving a priori demand estimates transport models using mobile phone data: a Rotterdam-region case. J. Urban Technol. 25 (2), 63–83.

Further reading

Geurs, K.T., Thomas, T., Bijlsma, M., Douhou, S., 2015. Automatic trip and mode detection with MoveSmarter: first results from the Dutch Mobile Mobility Panel. In: Procedia of the 10th International Conference on Survey Methods in Transport, pp. 247–262.