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ABSTRACT

Mobility as a Service (MaaS) is entering the transportation market. MaaS aims at the full integration of the existing transportation services and it offers tailored mobility packages to the user. In MaaS ecosystems, on-demand services play an important role as complement to public transport due to their flexibility. However, to date, most attention has been placed on individual on-demand services. This study focuses on Demand Responsive Transport (DRT): collective on-demand services. Using an on-line survey, we analysed the characteristics of the respondents who chose different modes of transport among their selected modes. Results find a distinctive pattern in the willingness of users to use different modes, with different levels in what could be considered as a multimodality ladder. The different rungs of it would be: 1st car (if available), 2nd public transport, 3rd DRT and 4th taxi-like services. This way, a person standing on the third rung would include car, public transport and DRT in their consideration set, but not taxi. This finding suggests that, if implemented in the right way, DRT services can attract a larger number of users than taxi-like services, especially in a MaaS ecosystem where initial barriers to try this service can be lessened.

1. Introduction

For decades, the concepts of 'transport' and 'integration' have been prominent in publications on transport policy (Givoni & Banister, 2010). Despite its long history, transport integration is still a misused and ambiguous term (Potter & Skinner, 2000), (Potter, 2010), even if there is a common understanding that it is a key precondition to reducing car use in favour of public transport systems (Chowdhury & Ceder, 2016), (Givoni & Banister, 2010), (Janic, 2001). Janic (2001) refers to integrated transport systems as systems providing smooth door-to-door services where different modes complement each other and where competition between different actors exists. The definition provided by Janic reflects what Mobility as a

Service (MaaS) is aiming at. MaaS combines different modes of transport seamlessly and offers prospective users both payment and ICT integration. In MaaS, all services are accessed via a mobility app and paid via a monthly subscription. Jittrapirom et al. (2017) and Kamargianni et al. (2016) provide a description of different MaaS schemes.

The new emerging on-demand services are to thank for the variety of tailored solutions that enable the existence of MaaS. They complement public transport, ideally as first-last mile or for rides where public transport is not a competitive alternative. Most of these on-demand modes offer individual transport, such as car-sharing, bike-sharing, car rental, taxi and Transport Network Companies (TNCs, such as Uber and Lyft). Even if these shared services provide a better utilization of the public space (less parking space is required) and of resources (not so many cars need to be manufactured) compared to a privately owned vehicle, their individual nature is not the most adequate for dense urban settlements. To this end, the introduction of Demand Responsive Transport (DRT) in cities as a core part of future MaaS schemes can conciliate the flexibility of on-demand services with the collectiveness needed in urban networks.

DRT systems are not a new solution. They were already included in the recommendations for urban transportation from the United States in 1968 (Cole, 1968). However, technology back then did not allow for large scale real-time systems. In 2012, Kutsuplus, the world's first real-time DRT system with fully automated dispatching, was implemented in Helsinki (Finland) as a pilot that operated until 2015 (Rissanen, 2016). Since then, other urban DRT schemes have appeared, such as Bridj (USA), Via (USA), UberPOOL (USA), Lyft Line (USA) or Abel (the Netherlands).

Various studies have focused on better understanding DRT usage. Based on a literature review of existing DRT services, Jain et al. (2017) identified individual characteristics of DRT users. On the other hand, where no revealed preference data was available, researchers have studied the expected modal shift towards DRT systems, either indirectly by means of hypothetical trade-offs between DRT and car or/and public transport (Frei et al., 2017), (Ryley et al., 2014), or directly by asking individuals their modal shift propensity towards DRT (Diana, 2010), (Gunay & Akgol, 2016). However, to the authors' knowledge, there is no study that explicitly considers DRT services and the demand they could attract in a MaaS context. Moreover, to the best of our knowledge, there is only one MaaS scheme in which the introduction of new DRT systems was considered: SHIFT – Project 100 (Project100, 2013), and this scheme was never fully operational (Schmidt, 2015). Therefore, this study explores the potential role of DRT systems in large-scale MaaS ecosystems previous to the existence of any system of its kind.

The rest of the paper is organised as follows: Section 2 explains the background upon which this study is built; Section 3 presents the hypothesis and the method employed; Section 4 describes the data used in this study, and Section 5 discusses the results. Finally, conclusions are presented in Section 6.

2. Background

Based on economic theory, stated preference (SP) experiments allow us to evaluate the choice of respondents in the form of a mathematical function (a utility function) that, as rational beings, we try to maximize. In order to forecast demand for new transport alternatives, the use of SP surveys is a common practice. SP surveys present respondents with hypothetical situations where they need to choose among the given alternatives, and where different attributes of those are presented. In the respondents' utility function, not only tangible trip related attributes are present (such as in-vehicle time, number of transfers or cost); extensive research has shown that the built environment, socio-economic characteristics, previous experience, attitudes, behaviour and habits all play an important role in modal choice. Moreover, individuals tend to consider a limited number of existing alternatives in their consideration set, and it is important to first understand which alternatives are considered by the individual before diving into the attributes that lead to the actual choice among those considered options. Therefore, as a first step, we need to understand which individuals include DRT in their consideration set.

To trigger a change in the consideration set of an individual, and most important, his modal shift, a change in habits is required. Numerous behavioural change models have been studied to better explain how travel mode choice takes place (other than the principle of users trying to maximise their utility) and what are its main determinant factors. Among these numerous models, (Politis et al., 2012) considers that the “Max Self Regulation Model”, also known as the MaxSem Model (Carreno & Welsch., 2009), is the best suitable model in the context of Flexible Transport Systems (as DRT systems are), since it presumes individual self (volunteer) intention for the behavioural change. The MaxSem Model, which resembles largely the Transtheoretical Model (Prochaska & Velicer, 1997), focuses on the diminution of car usage and considers that there are four different stages before people finally change their behaviour. Based on this framework, but making it general for any modal shift (and not just regarding car use), we can explain the different stages as follows:

- Stage 1: Pre-contemplative stage. Persons in this stage do not consider any modal shift.
- Stage 2: Contemplative stage. Persons in this stage are considering the use of alternative modes of transport different from the ones used.
- Stage 3: Preparation/action change. Individuals have decided on a strategy for modal shift or/and have tried the new transport alternative(s) in mind.
- Stage 4: Maintenance stage. Individuals in this stage have adopted the new mode of transport in their travel pattern.

Evidence from previous research shows that MaaS schemes do not merely ease the user's mobility experience, but that its implementation leads to changes in mobility patterns (Karlsson et al., 2017), (Sochor et al, 2015). Therefore, it could be argued that MaaS induces modal change. The simplicity of the service (it is unnecessary to have different subscriptions or to worry about what to do if a connection is missed) lowers the cost the individual needs to pay for engaging in the new behaviour, and the range of modes included in MaaS intrigues the individual who adopts MaaS to engage in more multimodal patterns. These characteristics can ease the step from the contemplative stage to stages 3 and 4 of the MaxSem theory, leading to actual mode shift. As such, the intention (the individual's motivation to engage in a particular behaviour), which is a prerequisite needed before engaging in a new behaviour (Armitage & Conner, 1999), is finally materialised in the performed behaviour. In this study, we analyse the characteristics of the individuals who are more likely to engage in a modal behaviour that includes DRT.

3. Hypothesis and method

Not all individuals are willing to choose different modes of transport in their mobility choices. Following the previously explained MaxSem Model, individuals in Stage 1 are not ready to include new modes in their mobility patterns. This means that, before diving deeper into which tangible trip attributes are more relevant in modal shift towards a specific mode, it is necessary to assess which of the individuals would, at least, consider the new mode (Stage 2 of the MaxSem model). Since it is not possible to measure the alternatives that an individual includes in his consideration set (they may not be materialised in their mobility patterns due to e.g. the mismatch with the built environment), we need an alternative method to measure this aspect. Labelled SP experiments with a wide spectrum of attribute levels provide the respondent with sufficient trade-offs for him to choose all alternatives displayed to him in some of the different scenarios shown. However, some of these alternatives will never be chosen if he is not including them in his consideration set. In other words, he will only ever choose an alternative, if this alternative reaches Stage 2 of the MaxSem model (i.e. is considered), while unconsidered alternatives will remain unchosen (they are still in the pre-contemplative stage). Based on this line of thought, we will consider all alternatives that were ever chosen in the SP experiment as alternatives that the individual includes in (at least) Stage 2, and refer to those as the ‘Stage 2 modal portfolio of the individual’, and, for more clarity along the paper, name it, in short, ‘modal portfolio’.

Based on the previous consideration, we formulate the following hypothesis:

- H1. Individuals who were not triggered enough to choose DRT in any of the presented scenarios are in the pre-contemplative stage and no modal shift can be expected from this group towards DRT.
- H2. Individuals who included DRT in their modal portfolio can be considered as potential users of the service, as they included DRT in Stage 2.
- H3. Due to the different multimodality levels of the population, DRT is mostly included in the modal portfolios of more multimodal individuals (that is, DRT is more likely to be added to an already multi-modal portfolio).

We analyse the characteristics of the individuals with the most recurrent modal portfolios. Socio-economic characteristics and current travel patterns are analysed as well. By means of this segmentation procedure, we aim at exploring the differences of the individuals with different modal portfolios, which leads us to our forth hypothesis:

- H4. Socio-economic characteristics and current mobility patterns vary among people with different modal portfolios.

Finally, we check if respondents who included the DRT mode in their modal portfolio also are prone to adopt MaaS. This check is especially important since the transition between Stage 2 and Stages 3 and 4 will be presumably facilitated by the introduction of a MaaS ecosystem (and Stages 3 and 4 are needed for modal shift). Our last hypothesis is thus:

H5. Multimodal users are most prone to adopt MaaS (and based on H3, DRT users will be among them).

4. Data

The data used for this analysis was obtained via an on-line survey conducted in December 2016 that targeted residents of the Amsterdam Metropolitan Area. A total of 797 respondents were considered valid respondents and used for the posterior analysis.

The sociodemographic characteristics of the sample and those of the national Dutch population are presented in Table 1. Respondents were all at least 18 years old and people aged 65 and older are a bit underrepresented in the sample compared to the national values. Since the analysis will consider car-holders and non-car-holders separately, Table 1 also includes the percentages relative to these two groups. Most of our respondents are car-holders (72.6%), which corresponds well with the numbers for households who have at least one car (71.3%), (Centraal Bureau voor de Statistiek (CBS), 2015a). Some differences can be accounted between the car-holder and the non-car holder sample, with the car-holder segment having a higher percent of men, middle age people, working individuals and a lower percentage of residents of the city of Amsterdam.

Table 1 Comparison between sample and Dutch population for different socio-economic variables. Source for the share population data: (Centraal Bureau voor de Statistiek (CBS), 2011), (Centraal Bureau voor de Statistiek (CBS), 2013), (Centraal Bureau voor de Statistiek (CBS), 2015b), (Centraal Bureau voor de Statistiek (CBS), 2016a), (Centraal Bureau voor de Statistiek (CBS), 2016b)

Socio-economic variable	Category	Dutch share population	Share sample	Car-holders sample (72.6%)	Non-car-holders sample (27.4%)
Gender	Male	49.6%	49.9%	53.9%	39.4%
	Female	50.4%	50.1%	46.1%	60.6%
Age	18* to 39	31.6%	34.5%	31.8%	41.7%
	40 to 64	44.9%	47.8%	50.9%	39.5%
	65 and above	23.4%	17.7%	17.3%	18.8%
Education	Low	28.0%	22.5%	20.6%	27.5%
	Average	41.3%	42.5%	42.7%	42.2%
	High	28.7%	34.4%	36.6%	28.5%
	Unknown	2.0%	0.6%	0.2%	1.8%
Work status	Working	62.5%	58.0%	65.5%	38.1%
	No working	37.5%	42.0%	34.5%	61.9%
Household	Single	37.6%	28.7%	20.9%	49.5%
	Couple	29.0%	36.0%	39.2%	27.5%
	With children	33.4%	35.3%	39.9%	22.9%
Residence	Amsterdam city	34.8%	28.7%	23.5%	42.7%
	Other **	65.2%	71.3%	76.5%	57.3%

* for the share population, the share is from 20 years old and not 18 years old
** Other within the Amsterdam Metropolitan Area

The survey included a mode choice SP experiment where each respondent had to choose from four different transport modes: public transport, shared transport services, individual transport services and car (the car option was only shown to car-holders with a driving licence). Figure 1 displays the description given to respondents for each of the modes. Note that we purposely denominated the on-demand services as ‘shared transport services’ and ‘individual transport services’ as to include all DRT types and all taxi-like services (i.e. both taxi and TNCs). To avoid the usage of these long names, we will refer to them from now on as DRT and taxi, respectively. An orthogonal design with blocking was used to design the SP experiment, for which Table 2 displays the attributes and the levels used. The choice modelling analysis of this experiment based on these attributes is presented in Alonso-González et al. (2017) in detail.

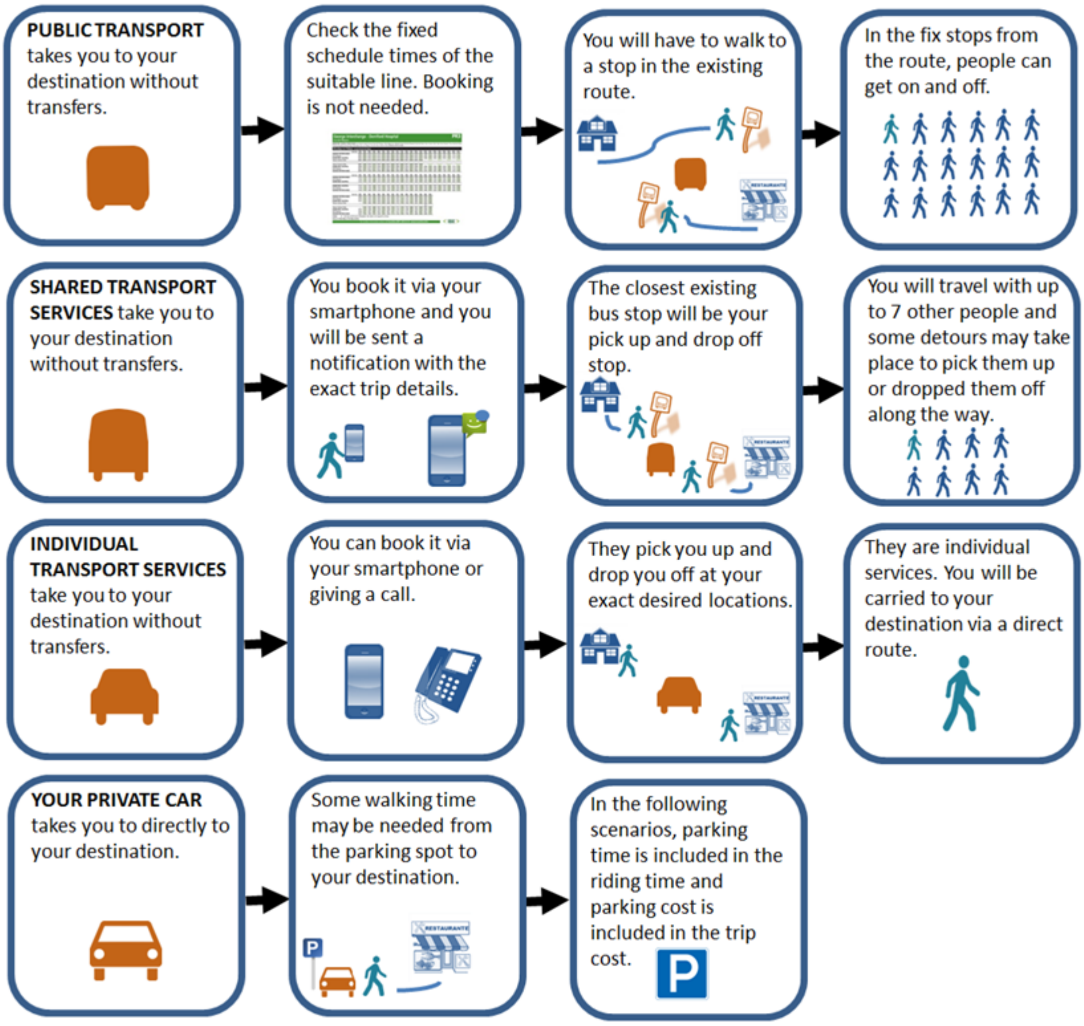

Figure 1: Information to respondents regarding the modes of transport shown

Table 2: Overview of attributes and attribute levels used in the SP experiment

Attribute	Attribute levels

Walking time PT	3 min	6 min	9 min
Walking time DRT	2 min	3 min	4 min
Walking time car	2 min	4 min	6 min
Departure delay PT	3 min	6 min	9 min
Departure delay DRT	2 min	4 min	6 min
Departure delay taxi	2 min	4 min	6 min
Riding time PT	26 min	38 min	50 min
Riding time DRT	24 min	35 min	46 min
Riding time taxi	20 min	25 min	30 min
Riding time car	23 min	33 min	43 min
Trip cost PT	1.30 €	2.30 €	3.30 €
Trip cost DRT	1.50 €	4.40 €	7.30 €
Trip cost taxi	6.50 €	13.80 €	21.10 €
Trip cost car	3.20 €	4.60 €	6.00 €
Frequency PT	15 min	25 min	35 min
Min booking time DRT	10 min	30 min	50 min
Min booking time taxi	2 min	6 min	10 min
Probability of ride being offered at the requested time (DRT)	20%	30%	40%
Probability of ride being offered 30 min after the requested time (DRT)	10%	20%	30%
Probability of ride being offered at the requested time (taxi)	30%	40%	50%
Probability of ride being offered 30 min after the requested time (taxi)	5%	10%	15%

This SP experiment was explained in the context of a leisure trip (as opposed to a business trip, a commuting trip or an educational trip). Two reasons led to this contextualisation of the survey: 1. Research has shown that mode shift behaviour is most likely for leisure trips (Vedagiri & Arasan, 2009) and 2. Previous research has identified shopping and social trips as the most recurrent purposes for DRT trips (Jain et al., 2017). Other than the SP experiment itself, the survey included questions on socioeconomic characteristics, ICT usage, mobility patterns and attitudes.

5. Results and discussion

5.1 Modal portfolio

Following the method explained in Section 3, we obtained the modal portfolios of each respondent. We did so by bundling together all the different alternatives that were chosen by each respondent in all 9 scenarios presented to them in the SP experiment. Figure 2 and Figure 3 show the share of the different modal portfolios obtained for car-holders and non-car-holders respectively. For car-holders, the percentages of unimodal, bimodal and portfolios with three modes in which DRT was included was 0%, 29% and 89%, while those for the car were 73%, 75% and 89% respectively (and 23%, 79% and 92% for PT).Similarly, for non-car-holders, the shares of unimodal and bimodal portfolios with DRT in them were 20% and 91% respectively (72% and 93% for PT). These numbers confirm the hypothesis that it is only in more multimodal portfolios that the DRT option is mostly included (H3).

From Figure 2 and Figure 3, we found four distinct main modal portfolios among car-holders and three main modal portfolios among non-car-holders, which include a different number of modes in them. A distinctive pattern can be observed in the willingness of users to use different modes, as if it were a sequential multimodality ladder. For car-holders, the different rungs of this ladder would be 1st car, 2nd public transport, 3rd DRT and 4th taxi-like services. This way, a person standing on the third rung would include car, public transport and DRT in their consideration set, but not taxi. A similar pattern is obtained for non-car-holders, leaving out the car rung from the ladder. This finding suggests that DRT services can be attractive to a larger market segment than taxi-like services. This result is especially interesting giving the large number of users that taxi-like services such as Uber have adopted in the last years.

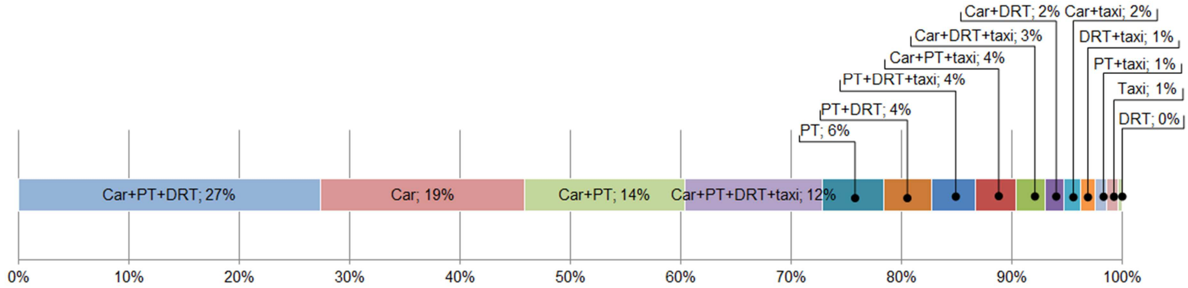

Figure 2 Shares of the different modal portfolios of car-holders

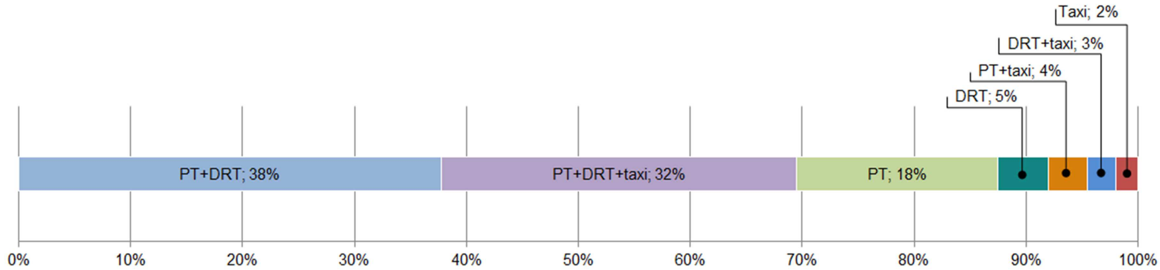

Figure 3 Shares of the different modal portfolios of non-car-holders

The percentage of car-holders and non-car holders with a unimodal portfolio is similar (19% car only respondents for car-holders and 18% PT only respondents for non-car-holders). These travellers have strong habitual patterns that they do not want to break regardless of the situation, or this outcome can also be due to these respondents having a “repeated ‘rational’ choice” that leads them to making the same decision again and again, as interpreted in Kroesen & van Cranenburgh (2016).

Since these findings are based on the results of a SP study, the obtained percentages cannot be extrapolated as modal portfolios’ shares for a given population. What can be deduced is that, in the population, modal portfolios differ principally in their multimodality degree. Moreover, from the results obtained, there is a promising trend that, other than the car mode which is still ingrained in the needs of many individuals, more collective modes are preferred to less collective modes (PT precedes in the multimodality ladder DRT, and DRT precedes taxi-like services) with the specified trade-offs between time and money. Therefore, users who are interested in taxi services (and not only them) are also potential users of DRT services, but not all individuals with PT in their modal portfolio show interest in DRT.

We will next analyse the characteristics of the respondents for the main modal portfolios. We will do so by means of an exploratory analysis. We use the segmentation approach, often used in transportation, where the modal portfolios are used as segmentation criterion. Only the main modal portfolios are studied individually, with all remaining individuals being included in a segment named as ‘other’. This way, attention is paid to the most common patterns only. These modal portfolios account for 72% of respondents for car-holders and 88% for non-car-holders. The ‘other’ modal portfolio ensures that, should a high percentage of respondents with a given characteristic not follow the mentioned mobility ladder in their patterns, this can also be identified and, if relevant, be further analysed. The main findings of this exploratory analysis are presented in the following subsections. In order to determine if respondents from different modal portfolios differed significantly with respect to the studied attributes, two tailed Pearson chi-square tests were performed.

5.2 Socioeconomic characteristics

Age, education level and working situation proved to be significant variables for the car-holder groups (results are depicted in Table 3). Gender, residence location, working situation and household net monthly salary were also analysed but differences among modal portfolios were not significant with a 95% confidence and, therefore, are not presented in this analysis. As can be observed in Table 1, the car-holder group of respondents differed from the total sample in having more males, fewer young adults, more high educated individuals, a higher percentage of workers, and less single people and residents of Amsterdam city.

Table 3: Car-holders’ socio-economic characteristics regarding their modal portfolio

Attribute (asymptotic signif., 2-sided)	Segments	Modal portfolios car-holders					N. respon-dents
		Car	Car + PT	Car + PT + DRT	Car + PT + DRT + taxi	Other	
Age (p=0.000)	18-34	8.2%	17.2%	29.9%	19.4%	25.4%	134
	35-49	22.6%	12.9%	28.4%	16.8%	19.4%	155
	50-64	22.6%	16.3%	22.6%	8.9%	29.5%	190
	65 +	16.0%	12.0%	30.0%	4.0%	38.0%	100
Education (p=0.00)	Low	27.5%	13.3%	15.0%	5.8%	38.3%	120
	Medium	17.0%	15.8%	26.3%	11.3%	29.6%	247
	High	14.2%	14.6%	34.9%	17.9%	18.4%	212
Working situation (p=0.014)	Full time worker	15,4%	14,3%	27,8%	18,1%	24,3%	259
	Part time worker	25,4%	15,5%	32,4%	7,0%	19,7%	71
	Self-employed	22,4%	10,2%	28,6%	14,3%	24,5%	49
	Retired	18,4%	16,3%	24,5%	2,0%	38,8%	98
	Other	17,6%	16,7%	23,5%	11,8%	30,4%	102

The age segmentation from Table 3 shows that young adults are most prone to include DRT services in their mobility choices, both with and without the taxi option, followed by the age group 35 to 49 years old. Senior citizens also show a large percentage of respondents in the

Car+PT+DRT modal portfolio, but not when also adding the taxi option to it. This oldest age group presents a large percentage of respondents in the ‘other’ segment, which suggests that this age segment would likely also not follow the presented multimodality ladder. The age group 50 to 64 years old are the least likely to exercise portfolios with the DRT option.

There seems to be a relation between the inclusion of DRT in the modal portfolio (with its following increase in the multimodality degree) and education level, with more educated respondents being more likely to include this collective on-demand mode, both with or without the taxi option. The lower educated respondents show a high percentage of other modal portfolios than the ones included in the analysis.

Looking at the working situation, full time workers and those self-employed behave similarly regarding their multimodality, with high shares of the two DRT modal portfolios, both with and without the taxi option. Part-time workers are more inclined to the DRT modal portfolio without the taxi option in it. The lower wages of part-timers may account for this result. This analysis also suggest that there is a higher interest towards DRT among 65+ers who are not yet retired.

Regarding the non-car-holder group, none of the socio-economic characteristics proved to be significant at the 95% level. The smaller sample of the non-car-holder sample (218) versus the car-holder sample (579) can have influenced this result. In order to compare both samples, the attributes age, education and working situation are depicted in Table 4.

Table 4: Non-car-holders’ socio-economic characteristics regarding their modal portfolio

Attribute (asymptotic signif., 2-sided)	Segments	Modal portfolios – non-car-holders				N. of respondents
		PT	PT + DRT	PT + DRT + taxi	Other	
Age (p=0.138)	18-34	14,1%	38,5%	41,0%	6,4%	78
	35-49	14,7%	38,2%	38,2%	8,8%	34
	50-64	18.5%	38.5%	26.2%	16.9%	65
	65 +	22.0%	31.7%	22.0%	24.4%	41
Education (p=0.764)	Low	17,2%	39,1%	26,6%	17,2%	64
	Medium	16.3%	34.8%	34.8%	14.1%	92
	High	17,7%	38,7%	35,5%	8,1%	62
Working situation (p=0.128)	Full time worker	18,2%	40,9%	25,0%	15,9%	44
	Part time worker	13,8%	37,9%	44,8%	3,4%	29
	Self-employed	0,0%	60,0%	40,0%	0,0%	10
	Retired	21,4%	26,2%	26,2%	26,2%	42
	Other	17,2%	37,6%	34,4%	10,8%	93

Similar to the car-user group, young adults in the non-car-holder group also have the most multimodal behaviour among all age groups followed by the early middle-agers (35-49). Unlike for car-holders, 65+ers in the non-car-holder group show the lowest share of the two shown DRT portfolios and no differences are seen in the shares of DRT portfolios regarding education level. What both samples share is the large percentage of seniors and low educated respondents that do not follow any of the modal portfolios of the multimodality ladder. Regarding working situation, the low share of the most multimodal portfolio among full time workers contrasts with the car-holder sample. A larger sample of non-car-holders would be necessary to determine statistically sound relationships concerning the different characteristics of different modal portfolios.

5.3 Current mobility patterns

Table 5 and Table 6 show the mobility patterns of respondents for the different modal portfolios. For car-holders (Table 5), not only is the behaviour of public transport usage (understood as bus/tram/metro and train), taxi usage and car usage statistically significant according to the mobility pattern, also bike plays an important role. The higher the PT and the bike usage rates are, the higher the adoption of DRT in the modal portfolio is. On the other hand, the car portfolio is most predominant among respondents who use PT less than once a year, and a high share of respondents who are not bike users have portfolios different from the represented in detail.

Regarding non-car-holders (Table 6), current mobility patterns do not seem to have had an effect in the selection of the PT+DRT portfolio. However, the share of respondents with the PT+DRT+taxi modal portfolio increased with an increase of usage rate in car and a decrease of usage rate in PT.

Our findings from Section 5.2 and 5.3 confirm our hypothesis that socio-economic characteristics and mobility patterns vary among people with different modal portfolios (H4).

Table 5 Car holders' current mobility patterns

Attribute (asymptotic signif., 2-sided)	Segments	Modal portfolios car-holders					N. of respondents
		Car	Car+PT	Car+PT +DRT	Car + PT + DRT + taxi	Other	
Bike usage (p=0.000)	Less than once a year	28.8%	12.7%	14.4%	8.5%	35.6%	118
	Monthly/yearly usage	21.0%	14.0%	22.3%	15.9%	26.8%	157
	Weekly usage	12.5%	16.1%	34.5%	12.5%	24.3%	304
Taxi usage (p=0.000)	Less than once a year	19.8%	15.7%	28.3%	9.9%	26.3%	445
	Monthly/yearly usage	13.6%	12.8%	23.2%	23.2%	27.2%	125
	Weekly usage	0.0%	0.0%	22.2%	0.0%	77.8%	9
Car usage (p=0.047)	Less than once a year	27.3%	18.2%	18.2%	18.2%	18.2%	11
	Monthly/yearly usage	11.3%	24.2%	24.2%	22.6%	17.7%	62
	Weekly usage	18.8%	13.6%	27.7%	11.3%	28.7%	506
Bus/tram/metro +train (p=0.000)	Less than once a year	43.1%	9.2%	17.7%	3.8%	26.2%	130
	Monthly/yearly usage	13.0%	17.5%	28.9%	12.7%	28.0%	332
	Weekly usage	5.1%	13.7%	32.5%	22.2%	26.5%	117

Table 6 Non-car holders' current mobility patterns

Attribute (asymptotic signif., 2-sided)	Segments	Modal portfolios – non-car-holders				N. of respondents
		PT	PT+DRT	PT + DRT + taxi	Other	
Bike usage (p=0.446)	Less than once a year	17.0%	34.0%	27.7%	21.3%	47
	Monthly/yearly usage	16.7%	41.7%	25.0%	16.7%	36
	Weekly usage	17.0%	37.0%	36.3%	9.6%	135
Taxi usage (p=0.152)	Less than once a year	19.1%	37.7%	30.2%	13.0%	162
	Monthly/yearly usage	10,9%	36,4%	40,0%	12,7%	55
	Weekly usage	0.0%	0.0%	0.0%	100.0%	1
Car usage (p=0.095)	Less than once a year	27.3%	34.1%	22.7%	15.9%	44
	Monthly/yearly usage	12.0%	44.0%	30.0%	14.0%	100
	Weekly usage	17.6%	29.7%	41.9%	10.8%	74
Bus/tram/metro + train (p=0.145)	Less than once a year	14.8%	18.5%	40.7%	25.9%	27
	Monthly/yearly usage	14.2%	41.5%	34.0%	10.4%	106
	Weekly usage	21.2%	37.6%	28.2%	12.9%	85

It is also important to analyse the complete multimodal patterns, and not only the usage of each mode individually, since multimodal users are also more likely to change their mobility behaviour than unimodal users (Kroesen, 2014). We analysed the weekly patterns for being this the most commonly accepted period to consider multimodality (Buehler & Hamre, 2014), (Nobis, 2007), and we included car, train, bus/tram/metro and taxi in the analysis. Most car-holders had a unimodal weekly car usage (70%), while the most recurrent pattern for the non-car-holder sample was the lack of usage of any of these modes on a weekly basis (36%). Also interesting for our analysis are the modes that are used at least yearly, and how current modal patterns in a larger time range relate to the different mobility portfolios. This is represented in Figure 4 and Figure 5. During the course of a year, the variety of situation to which the individual is exposed to can trigger him to use all available modes in his consideration set at least once. As a result, the left side of Figure 4 and Figure 5 would represent their consideration set in the course of a year. From the figures, a relation between these yearly mobility patterns and their modal portfolios can be seen. This supports hypothesis 1 and 2 (H1 and H2) that the method used in this study can help identify individuals that are predisposed to include DRT services in their consideration set in a future scenarios.

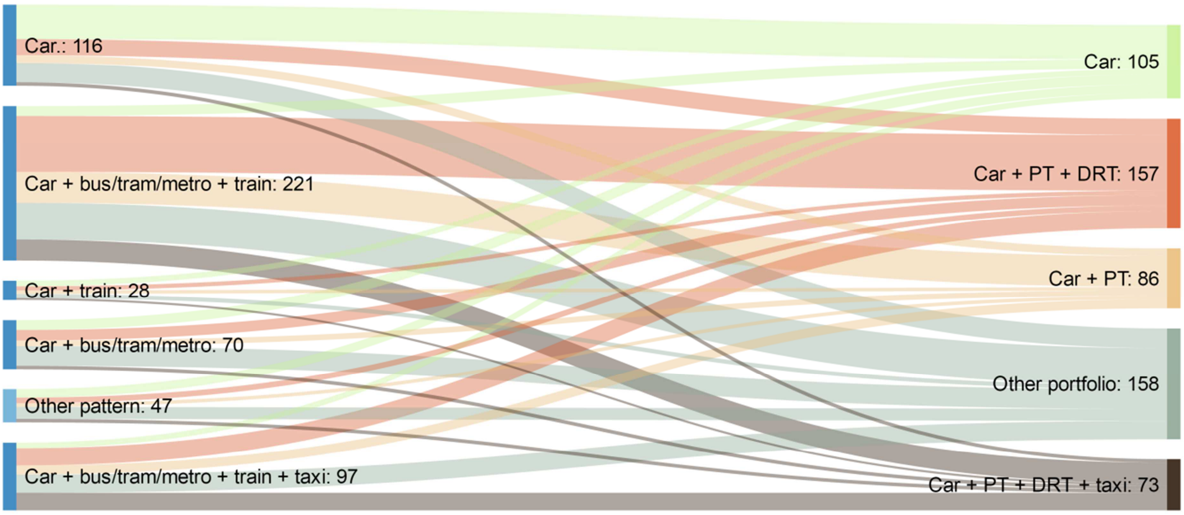

Figure 4 Relation between current yearly mobility patterns of car-holders (left) and their modal portfolio (right)

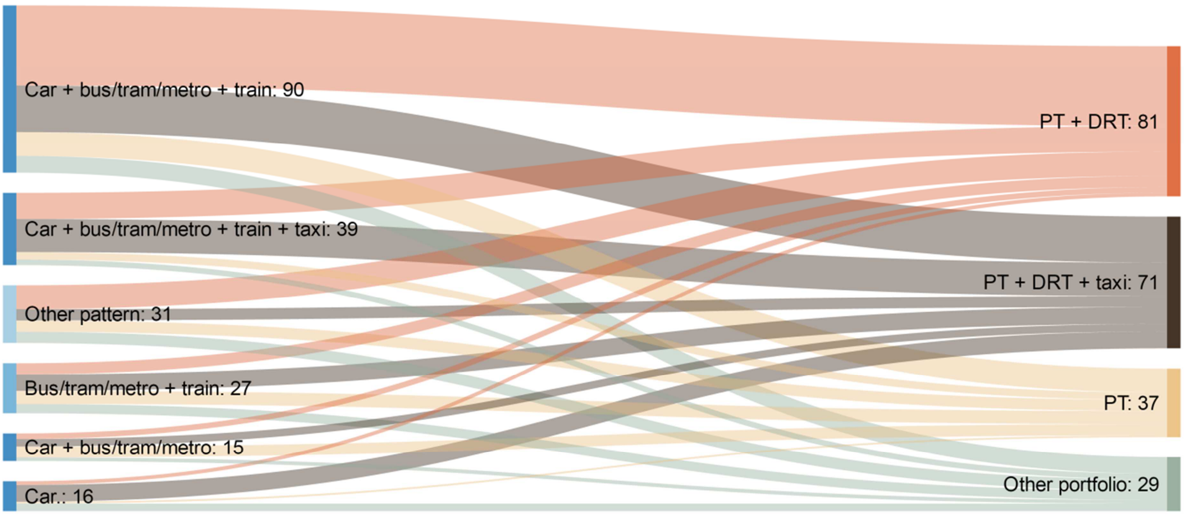

Figure 5 Relation between current yearly mobility patterns of non-car-holders (left) and their modal portfolio (right)

5.4 Compatibility with MaaS characteristics

This section looks at the inclination of respondents from the different modal portfolios to engage in MaaS. Sections 5.2 and 5.3 analysed respondents' socio-economic characteristics and travel patterns for the different modal portfolios, but still nothing has been said about whether the people engaging in the modal portfolios that contain DRT are also likely to switch to that behaviour (that is, stepping from Stage 2 to Stages 3 and 4 of the MaxSem Model). Since, as mentioned in Section 2, MaaS easies the usage of new modes, a check of the susceptibility to engage in MaaS according to the modal portfolios is of importance. MaaS offers tailored packages to the user, and offers ICT and payment integration. As such, three indicators have been chosen in this respect: the availability of a PT subscription (since PT should be the backbone of MaaS (UITP, 2016) and MaaS involves some kind of membership), the usage of mobility apps (needed in MaaS), and the opinion towards mobile payments (since mobile payments ease the payment procedure among different operators). Results are shown in Table 7 and Table 8.

Table 7 Car-holders' MaaS compatibility characteristics

Attribute (asymptotic signif., 2-sided)	Segments	Modal portfolios car-holders					N. of respondents
		Car	Car + PT	Car + PT + DRT	Car + PT + DRT + taxi	Other	
Public transport subscription (p=0.000)	No	22.1%	14.4%	25.1%	9.4%	29.0%	403
	Yes	9.1%	15.9%	31.8%	19.9%	23.3%	176
Mobility app - weekly usage (p=0.000)	No	25.2%	15.2%	24.5%	7.5%	27.6%	322
	Yes	9.3%	14.4%	30.4%	19.1%	26.8%	257
Opinion towards payment via app (p=0.000)	Negative	29.3%	16.0%	19.3%	5.3%	30.0%	150
	Neutral	18.3%	17.8%	27.2%	8.3%	28.3%	180
	Positive	11.2%	12.0%	31.7%	20.1%	24.9%	249

Table 8 Non-car-holders' MaaS compatibility characteristics

Attribute (asymptotic signif., 2-sided)	Segments	Modal portfolios – non-car-holders				N. of respondents
		PT	PT+DRT	PT + DRT + taxi	Other	
Public transport subscription (p=0.505)	No	16.5%	39.4%	28.4%	15.6%	109
	Yes	17,4%	34,9%	36,7%	11,0%	109
Mobility app - weekly usage (p=0.047)	No	21.9%	37.1%	24.8%	16.2%	106
	Yes	12.4%	37.2%	39.8%	10.6%	113
Opinion towards payment via app (p=0.072)	Negative	23,5%	45,6%	20,6%	10,3%	68
	Neutral	11,4%	31,4%	38,6%	18,6%	70
	Positive	16,3%	35,0%	37,5%	11,3%	80

Among car-holders, around 50% of the respondents who engaged in any of the three attributes from Table 7, chose one of the two shown modal portfolios that contained DRT modes (in contrast to the overall car-holders, who chose it 39%). Among non-car-holders (Table 8), a MaaS prone behaviour (i.e., a higher engagement in the shown attributes) was only visible for respondents of the modal portfolio that included DRT together with the taxi option.

The findings in this section confirm our hypothesis that the more multimodal users are the most prone to adopt MaaS (and therefore, include DRT in their future mobility patterns) (H5).

6. Conclusions

MaaS is getting growing attention from both scientists and practitioners. It is regarded as the key to compete with the private car in personal mobility and it offers full integration of the existing mobility services. MaaS schemes should be implemented in cities with an adequate PT system (Li & Voege, 2017) so that they can have PT as their backbone (UITP, 2016) and on-demand services just as complements. To date, attention has been mostly placed on individual on-demand services. However, collective on-demand services (DRT services) may be better suitable for the dense structure of our cities.

To the best of the authors' knowledge, there are no current MaaS schemes that include DRT systems. Therefore, their role in MaaS is not yet possible to measure empirically. To overcome this issue, in this paper, we perform an exploratory analysis based on the results of a SP experiment. The SP experiment is used to study the modal consideration set of the different respondents (referred to as modal portfolio) and not the trade-offs between different attributes. Two main reasons led us to this approach: 1. DRT will never be adopted by individuals who do not (even) include this mode in their consideration set and 2. MaaS easies the usage of different modes of transport thanks to the integration it provides, facilitating the inclusion of the considered modes into their new mobility patterns. As a result, the likeliness that an individual who included DRT in his consideration set (modal portfolio) will also include this mode in his mobility patterns increases in MaaS schemes.

The obtained results find a distinctive pattern in the willingness of users to use different modes. This pattern exhibits different multimodality levels in what could be conceptualized as a sequential multimodality ladder, with the DRT rung coming after car and PT but before taxi-like services. Socioeconomic characteristics, current mobility patterns and car ownership play a role in the likelihood of individuals to include DRT services as part of their mobility choices. For car holders, individuals aged 50 or younger, high educated people and the working population are more prone to include DRT in their mobility choices. For non-car-holders, a more homogeneous pattern is found. Regarding current mobility patterns, more multimodal individuals are also more likely to engage in DRT usage. Moreover, it is these multimodal individuals that are more likely to engage in MaaS schemes according to the performed compatibility check.

The findings of this study suggest that the majority of individuals who are likely to engage in MaaS schemes consider more collective services before also engaging in individual on-demand services. Results regarding the implementation of DRT services in MaaS schemes are promising and suggest that a large acceptance of this mode can be achieved, which would contribute to a more efficient and sustainable urban mobility.

While this study provides some valuable findings, it is based on an exploratory analysis and more research is necessary to further confirm the examined hypothesis. A limitation of this study is that respondents were not directly asked about their susceptibility to adopt DRT or MaaS in the future and this is just measured in an indirect manner. Future research could include direct questions to respondents addressing their susceptibility to include DRT and MaaS in their mobility and compare their responses with the segments obtained indirectly using their SP choices. Another limitation of this method comes from the alternatives incorporated in the SP experiment itself. The inclusion of other modes such as car-sharing or bike could have been added for a more complete MaaS scenario; on the other hand, the inclusion of the opt-out alternative would have led the respondent to make more realistic choices. Regardless the limitations, this study pioneers in the consideration of DRT services in future MaaS schemes and provides initial insights of its potential usage and the market segment it may penetrate into.

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References

Alonso-González, M. J., van Oort, N., Cats, O., & Hoogendoorn, S. (2017). Flexibility or uncertainty ? Predicting modal shift towards demand responsive public transport. In *International Choice Modelling Conference 2017*.

Armitage, C. J., & Conner, M. (1999). The Theory of Planned Behaviour: Assessment of Predictive Validity and `Perceived control'. *British Journal of Social Psychology*, *38*, 35–54. https://doi.org/10.1348/014466699164022

Buehler, R., & Hamre, A. (2014). The multimodal majority? Driving, walking, cycling, and public transportation use among American adults. *Transportation*, *42*(6), 1081–1101. https://doi.org/10.1007/s11116-014-9556-z

Carreno, M., & Welsch., J. (2009). *MaxSem: Max Self Regulation Model: Applying theory to the design and evaluation of Mobility Management projects*.

Centraal Bureau voor de Statistiek (CBS). (2011). Working force data. Retrieved from http://statline.cbs.nl/Statweb/publication/?VW=T&DM=SLNL&PA=82647ned&D1=a&D2=0&D3=0,9-13&D4=44&HD=150317-1707&HDR=G3&STB=G1,G2,T&P=T

Centraal Bureau voor de Statistiek (CBS). (2013). Education data. Retrieved from http://statline.cbs.nl/statweb/publication/?vw=t&dm=slen&pa=71882eng&d1=0-1&d2=a&d3=10-15&d4=(l-10)-l&hd=151216-1430&la=en&hdr=g3&stb=g1,t,g2

Centraal Bureau voor de Statistiek (CBS). (2015a). Huishoudens in bezit van auto of motor; huishoudkenmerken. Retrieved June 19, 2017, from http://statline.cbs.nl/Statweb/publication/?DM=SLNL&PA=81845ned&D1=0-1&D2=a&D3=0-2,13-31&D4=l&VW=T

Centraal Bureau voor de Statistiek (CBS). (2015b). Population per municipality. Retrieved from http://statline.cbs.nl/statweb/publication/?vw=t&dm=slnl&pa=70233ned&d1=0&d2=0&d3=0-101&d4=(l-6)-l&hd=160205-1119&hdr=t,g3&stb=g1,g2

Centraal Bureau voor de Statistiek (CBS). (2016a). Household composition data. Retrieved from http://statline.cbs.nl/statweb/publication/?vw=t&dm=slnl&pa=37975&d1=0-5,10,15,19&d2=0&d3=0,5,10,15,(l-4)-l&hd=151214-1158&hdr=t&stb=g1,g2

Centraal Bureau voor de Statistiek (CBS). (2016b). Population age and gender data. Retrieved from http://statline.cbs.nl/Statweb/publication/?DM=SLNL&PA=37296ned&D1=0-51&D2=0,10,20,30,40,50,(l-1)-l&VW=T

Chowdhury, S., & Ceder, A. (Avi). (2016). Users' willingness to ride an integrated public-transport service: A literature review. *Transport Policy*, *48*, 183–195. https://doi.org/10.1016/j.tranpol.2016.03.007

Cole, L. M. (1968). *TOMORROW'S TRANSPORTATION: NEW SYSTEMS FOR THE URBAN FUTURE*. Retrieved from http://ntl.bts.gov/lib/24000/24500/24577/Tomorrows%7B_%7DTransportation%7B_%7Dsrch.pdf%5Cnhttps://trid.trb.org/view/129263

Diana, M. (2010). From mode choice to modal diversion: A new behavioural paradigm and an application to the study of the demand for innovative transport services. *Technological Forecasting and Social Change*, *77*(3), 429–441. https://doi.org/10.1016/j.techfore.2009.10.005

Frei, C., Hyland, M., & Mahmassani, H. S. (2017). Flexing service schedules: Assessing the potential for demand-adaptive hybrid transit via a stated preference approach. *Transportation Research Part C: Emerging Technologies*, *76*, 71–89. https://doi.org/10.1016/j.trc.2016.12.017

Givoni, M., & Banister, D. (2010). *Integrated Transport: from policy to practice*. Routledge.

Gunay, B., & Akgol, K. (2016). Estimation of Modal Shift Potential for a New Form of Dial-A-Ride Service. *Journal of Public Transportation*, *19*(2). https://doi.org/10.5038/2375-0901.19.2.5

Jain, S., Ronald, N., Thompson, R., & Winter, S. (2017). Predicting susceptibility to use demand responsive transport using demographic and trip characteristics of the population. *Travel Behaviour and Society*, *6*, 44–56. https://doi.org/10.1016/j.tbs.2016.06.001

Janic, M. (2001). Integrated transport systems in the European Union: An overview of some recent developments. *Transport Reviews*, *21*(4), 469–497. https://doi.org/10.1080/01441640110042147

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 Planning*, *2*(2), 13–25. https://doi.org/10.17645/up.vXiX.XXX

Kamargianni, M., Li, W., Matyas, M., & Schäfer, A. (2016). A Critical Review of New Mobility Services for Urban Transport. In *Transportation Research Procedia* (Vol. 14, pp. 3294–3303). https://doi.org/10.1016/j.trpro.2016.05.277

Karlsson, M., Sochor, J., Aapaoja, A., Eckhardt, J., & König, D. (2017). *Deliverable 4: Impact Assessment. MAASiFiE project funded by CEDR.* Retrieved from http://www.vtt.fi/sites/maasifie/PublishingImages/results/CEDR_Mobility_MAASIFIE_Deliverable_4_Revised_Final.pdf

Kroesen, M. (2014). Modeling the behavioral determinants of travel behavior: An application of latent transition analysis. *Transportation Research Part A: Policy and Practice*, *65*, 56–67. https://doi.org/10.1016/j.tra.2014.04.010

Kroesen, M., & van Cranenburgh, S. (2016). Revealing transition patterns between mono- and multimodal travel patterns over time: A mover-stayer model. *European Journal of Transport and Infrastructure Research*, *16*(4), 754–771.

Li, Y., & Voege, T. (2017). Mobility as a Service (MaaS): Challenges of Implementation and Policy Required. *Journal of Transportation Technologies*, *7*, 95–106. https://doi.org/10.4236/jtts.2017.72007

Nobis, C. (2007). Multimodality: Facets and Causes of Sustainable Mobility Behavior. *Transportation Research Record*, *2010*, 35–44. https://doi.org/10.3141/2010-05

Politis, I., Papaioannou, P., & Basbas, S. (2012). Integrated choice and latent variable models for evaluating flexible transport mode choice. *Research in Transportation Business and Management*, *3*, 24–38. https://doi.org/10.1016/j.rtbm.2012.06.007

Potter, S. (2010). Transport integration - an impossible dream? In *Universities Transport Studies Group Annual Concerence, 5-7 January 2010, University of Plymouth.* (pp. 1–10). Retrieved from http://oro.open.ac.uk/19719/

Potter, S., & Skinner, M. J. (2000). On transport integration: a contribution to better understanding. *Futures*, *32*(3), 275–287. https://doi.org/10.1016/S0016-3287(99)00097-X

Prochaska, J. O., & Velicer, W. F. (1997). The transtheoretical model of health behavior change. *American Journal of Health Promotion*, *12*(1), 38–48.

Project100. (2013). Project100 | Drive. Ride. Bike. Fly. Connect. Retrieved June 16, 2017, from http://www.goproject100.com/

Rissanen, K. (2016). *Kutsuplus – Final Report*. Helsinki. Retrieved from https://www.hsl.fi/sites/default/files/uploads/8_2016_kutsuplus_finalreport_english.pdf

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. *Research in Transportation Economics*, *48*, 364–372. https://doi.org/10.1016/j.retrec.2014.09.064

Schmidt, W. (2015). Las Vegas Transportation Startup SHIFT Winds Down. Retrieved June 28, 2017, from https://tech.co/las-vegas-startup-shift-shuts-down-2015-04

Sochor, J., Stromberg, H., & Karlsson, I. C. M. (2015). Implementing Mobility as a Service Challenges in Integrating User, Commercial, and Societal Perspectives. *Transportation Research Record: Journal of the Transportation Research Board*, (2536).

UITP. (2016). Mobility as a service: an alternative to owning a car | UITP. Retrieved December 7, 2016, from http://www.uitp.org/news/maas-finland

Vedagiri, P., & Arasan, V. T. (2009). Modelling modal shift due to the enhanced level of bus service. *Transport*, *24*(2), 121–128.