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Mobility-as-a-Service: does it contribute to sustainability?

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Abstract The promise of Mobility-as-a-Service (MaaS) is that it decreases the need to own a car and contributes to a more sustainable transport system. However, MaaS also offers relatively easy access to car-based travel alternatives which may result in substituting public transport trips by car trips. An important question therefore is: which type of traveler is going to adopt MaaS and which impact is this going to have on their mode choices? This paper explores this question by presenting the results of a stated choice experiment conducted in the Netherlands. Travelers are presented with MaaS bundles that vary in accessibility to transport services and price and they respond to a range of questions about bundle adoption, change in transport mode, and willingness to shed one or more cars. The results suggest that if MaaS bundles are given for free to the travelers, this has the potential to change their frequency of mode use. For example, if the MaaS bundel includes unlimited bus, tram and metro (BTM), even travelers who solely use car will then use BTM more. However, realizing this potential is not very likely, because when travelers have to pay for MaaS, adoption rates are rather low, in particular of those who use car the most. In addition, the willingness of car owners to shed their cars is very low, suggesting that currently MaaS is not conceived as a viable alternative for car-ownership. On the other hand, current public travelers seem most interested in MaaS and results indeed as expected suggest that this increases their car use. Overall, the trends reported in this paper adds to a growing insight that MaaS' contribution to sustainability may be smaller than generally believed.

I. INTRODUCTION

Mobility-as-a-Service (MaaS) (Ambrosino et al, 2016) is widely hoped to induce a shift from a transport system largely based on private car-ownership towards a system in which transport vehicles are shared. MaaS integrates a variety of transport modes, such as public transport, shared car, shared bicycle, taxi and hail-ride services into a single digital platform, which allows travelers to seamlessly plan, book and pay for any trip (e.g., Kamargianni et al., 2016). Public transport (PT) is generally regarded as the backbone of MaaS and is complemented with relatively easy access to shared car, share bicycle, taxi and ride-hailing services. MaaS is therefore assumed to provide a suitable alternative for door-to-door car transport and hoped to decreases the need to own a car. Consequently, it is expected to result in less car mobility and therefore contribute to a more sustainable transport system.

The expected positive contribution to sustainability is however not self-evident. In a pay-as-you-go MaaS system, it remains to be seen whether integration of all transport services in a digital platform will provide sufficient added value to induce car owners to start using MaaS and shed their cars on a large scale. Traveling by PT, certainly if it involves making transfers, typically takes longer than door-to-door car transport. And although the total costs of using MaaS may be cheaper than the total costs of owning and using a car, in their cost assessment, travelers tend to forget sunk car cost (e.g., car depreciation, tax, insurance, etc.) and typically compare only the marginal car costs (e.g., fuel, parking) with costs of transport alternatives (Willumsen, 2019). Consequently, car drivers perceive the costs of making use of MaaS services as rather high. If however MaaS systems offer monthly subscriptions (e.g., Esztergár-Kiss and Kerényi, 2019; Caiati et al, 2020; Guidon et al. 2020), which involves that travelers pay a fixed amount of money per month to make use of a bundle of transport services, this may increase the probability that all car costs are taken into account in the comparison. Moreover, MaaS bundles may result in lower total costs compared to pay-as-you go use. Hence, MaaS bundles may offer a complete mobility service alternative for car transport that may be cheaper than owning a car, which may induce car owners to shed their cars and start traveling in a more flexible way (Hietanen, 2014). However, there is only limited empirical evidence to what extent car owners are willing to do this.

Also for another reason it remains to be seen whether Maas can contribute to a more sustainable transport system. MaaS bundles are likely to be very interesting for current PT users (e.g. Jittrapirom et al., 2018; Alonso-González et al. 2020), because they offer easy access to additional flexible transport modes, such as shared bike, shared car, taxi, and ride hail services. This a welcome supplement for PT travelers when a destination cannot be reached easily, for easy access and egress to and from PT stops and stations, and as an alternative for PT in case of delays or if a connection is missed. However, if current PT travelers indeed adopt MaaS on a large scale and start using the flexible car-based transport options included in their MaaS bundles, this may actually increase the total car travel of this group. As a consequence, MaaS will only contribute to a more sustainable transport system if it succeeds in attracting sufficient numbers of current car drivers that offset the likely increase in car travel of the current PT travelers. Hence, important questions to be answered involve which kind of travelers are going to adopt MaaS and how this will influence their mode choice. This question can only be fully answered after large-scale introduction of MaaS, nevertheless it is important to gain insight now in order to help avoiding or mitigating MaaS implementations that have undesirable consequences.

This paper therefore intends to explore the raised questions by reporting the results of a stated choice experiment, which is conducted in the Netherlands among 203 travelers. Travelers are presented various MaaS bundles that vary in transport services included and in cost structure. For each bundle, they respond to a series of questions about adoption, both if they receive the bundle for free and if they have to pay for it, changes in mode choice and willingness to shed one or more cars. The results are presented for the entire sample and are broken down for different modality style groups. These groups are identified by applying latent class cluster analysis based on the frequency of the travelers' current mode use.

The remader of this paper is structured as follows: first the methodology will be described in more detail. Then the modality styles are identified. This is followed by presenting and discussing the results. Finally, conclusions are drawn and policy implications are discussed.

II. METHODOLOGY

First, the construction of the stated choice experiment is discussed. The first columns of Table 1 presents **the** attributes that were varied in the stated choice experiment. The following columns include the attribute-levels, which express the mobility service levels included in the bundle, accompanied by their cost structure when relevant. These levels are based on transport services currently offered in the Netherland, which was verified in interviews with experts in the field. An orthogonal fractional factorial design was used to arrive at 16 MaaS bundle alternatives, which were blocked into four blocks. Each respondent is randomly shown only one block of four MaaS bundle alternatives.

Table 1 – Transport service attributes and levels

	1	**2**	**3**	**4**
Rail	Always discount (20%)	Weekend free, and off-peak discount 40%)	Free off-peak and weekend	Unlimited travelling
BTM	Always discount (20%)	Unlimited travelling		
Car-sharing	€4 / hour + €0,29 / km	€3 / hour + €0,24 / km		
Bike	€1,00 per trip up to 40 min	Unlimited trips up to 40 min		
Taxi/ride-hailing	0 free trips up to 5km	2 free trips up to 5km	4 free trips up to 5km	6 free trips up to 5km
Transferable credits	No	Yes		
Costs	€50	€175	€300	€425

For each constructed MaaS bundle, respondents were requested to answer to a range of questions. First, travelers needed to assume that the bundle was given to them, for example fully paid by their employer. To that effect, the MaaS bundle was shown without costs and the following question was posed: "If you woul possess the bundle shown above, would you change your mode use of the following transport modes, and if so, to what extent?". This was separately assessed for the following 7 modes: private car, shared car, private bike, shared bike, train, BTM (Bus, Tram, Metro) and taxi. Responses were measured on a five-point ordinal scale. Although only the qualitative category labels were shown in the experiment, the following percentages were provided in the explanation of the measurement task to give the respondents any idea how to interpret the response categories: (1) a lot less: at least -50%; (2) a little less: between 0 and -50%, (3) the same; (4) a little more: between 0 and 50% more; a lot more: at least 50% more. The second question involved the willingness of travelers to shed one or more cars. Depending on the respondent's current situation, one of the following questions was posed. Respondents currently owning one or more cars were asked whether they would be willing to get rid of none, one, or multiple cars. Respondents not owning a car were asked whether or not they would still purchase a car in the future. Finally, respondents owning a lease car were asked whether or not they would still want their lease-car. Only after these questions, the levels of the price attribute was shown and respondents were asked whether or not they were willing to adopt the bundle themselves for the presented price.

The experiment was included in a web-based questionnaire, and was preceded with questions about the current travel behavior. Among others, respondents indicated how often they currently use each of the 7 modes mentioned before. They could respond on an 8-point ordinal scale running from (almost) every day to less than once a year. Then the MaaS concept was explained by describing the nine core concepts of MaaS as discussed by Jittrapirom et al. (2017). For respondents who wished further clarification of the MaaS concept, a link to a video was provided (https://vimeo.com/229846680). The last part of the questionnaire posed questions about socio-demographic variables.

Respondents were recruited in the fall of 2019 by contacting the social network of the first author and by providing a link to the questionnaire on social media platforms Facebook, Linkedin and Twitter. This resulted in 203 completely filled out questionnaires. Compared to the overall population, the following categories are somewhat overrepresented in this sample: males, highly educated, urban dwellers, and car owners, while the variables age, income, job, and number of household members seem to follow Dutch population distributions fairly well. The sample must be regarded as a convenience sample, however, since all categories are fairly well presented, we believe the sample is suitable for the purpose of this paper, that is, to gain a first insight into potential behavioral changes and adoption shares of MaaS.

In order to analyze the data, first mobility styles were identified from the current mode frequency variables by applying Latent Class Cluster Analysis (LCCA), similar to Molin et al., 2016. LCCA is a flexible method to segment respondents into classes that are homogeneous with respect to indicators that characterize their responses (Nylund et al., 2007). The method assumes that each respondent is a member of a single latent clusters. These clusters are latent because they cannot be observed directly and they emerge in the analysis. Different number of classes are tried and compared. Based on fit measures, a final solution is chosen. The classification into clusters is probabilistically based on observed indicators, which is this paper is the frequency of use of the 7 distinguished transport modes mentioned before. The software package LatentGold was applied to conduct this analysis. Next, it is examined how the inclusion of transport services in the MaaS bundle affects changes in mode use by applying ordinal regression analyses. Finally, MaaS bundle adoption is analyzed by applying binary logistic regression.

III. RESULTS

Travel modality style groups

First, we discuss the identified modality styles. A five cluster model apeared to have the best model fit. The within group percentages of mode use of the five clusters are presented in Table 2. To ease interpretation of the results, the highest within cluster percentage per mode is made bold. The clusters where labeled as follows with their sample shares between brackets: 1) **PT+Bike** (34%), 2) **Car mostly** (22%), 3) **Bike+Car** (18%), 4) **PT+Car** (16%), 5) **Flex** (10%). For further analysis, every respondent is assigned to only one of the five clusters based on the highest predicted class membership probability.

Table 2 – Within mode use frequency percentages of the five identified modality style clusters (based on LCCA)

	Bike +PT	**Car mostly**	**Bike +Car**	**PT +Car**	**Flex**
sample share	**34%**	**22%**	**18%**	**16%**	**10%**
car use					
5-7 days/wk #	0%	**94%**	3%	1%	0%
1-4 days/wk	11%	6%	**71%**	**62%**	4%
>= 1/mth	42%	0%	24%	33%	28%
<1/mth	**48%**	0%	2%	4%	**67%**
Bike					
5-7 days/wk	**78%**	26%	**84%**	**59%**	16%
1-4 days/wk	18%	29%	13%	26%	26%
>= 1/mth	3%	15%	2%	7%	16%
<1/mth	2%	**29%**	1%	8%	**42%**
Train					
5-7 days/wk	30%	0%	0%	42%	0%
1-4 days/wk	**55%**	5%	14%	**49%**	21%
>= 1/mth	13%	21%	35%	9%	39%
<1/mth	2%	**74%**	**49%**	1%	**40%**
BTM					
5-7 days/wk	22%	0%	1%	19%	0%
1-4 days/wk	**43%**	6%	16%	**43%**	11%
>= 1/mth	24%	18%	29%	25%	25%
<1/mth	11%	**75%**	**55%**	12%	**64%**
shared bike					
-7 days/wk	1%	0%	0%	1%	1%
1-4 days/wk	11%	0%	0%	11%	11%
>= 1/mth	22%	2%	2%	22%	23%
<1/mth	**66%**	**98%**	**98%**	**66%**	**64%**
shared car					
1-2 day/wk	0%	0%	0%	0%	4%
>= 1/mth	2%	0%	0%	1%	26%
<1/mth	17%	6%	0%	14%	**42%**
<1/yr	**81%**	**94%**	**100%**	**85%**	27%
taxi					
1-2 day/wk	1%	0%	0%	0%	2%
>= 1/mth	6%	3%	2%	3%	16%
<1/mth	**51%**	43%	38%	42%	**58%**
<1/yr	42%	**54%**	**59%**	**55%**	24%

categories are merged here to ease interpretation.

Mode use change

To examine how the inclusion of transport services in the MaaS bundle affects the reported change in frequency of mode use, the results of the estimated ordinal regression models are presented in Table 3. Because of limitations of space, only the models estimated for the conventional motorized modes car, train and BTM are presented. The first results column (T) presents the results of the entire sample. Statistically significant coefficients (Wald statistic > 3.84) are presented in bold. The results indicate that only a few coefficients are statistically significant. This is caused by the fact that most respondents for most modes indicate that they would not change their frequency of use, which is itself is an interesting observation. A further reason is that the number of observations is rather limited, which in particular applies to the results per modality style cluster. Hence, the power of conducting statistical tests is low, consequently the coefficients need to be relatively large in order to become statistically significant. To avoid making a type 2 error, that is falsely concluding that there is no effect in the population, we did not remove any non-significant coefficients. The results thus show all possible trends whether or not statistically significant, and should therefore be cautiously interpreted. Note that the estimated thresholds are included in the Tables to present complete modeling results, but these do not offer a content wise interesting interpretation.

Table 3 – Change in frequency of transport mode use (ordinal regression model)

	T	**B+PT**	**C**	**B+C**	**PT+C**	**FLEX**
CHANGE IN CAR USE						
tresholds						
a lot less	**-3.89**	**-3.94**	**-4.33**	**-3.87**	**-4.88**	-1.71
a little less	**-1.56**	**-1.95**	**-1.49**	**-1.14**	-2.18	-0.22
the same	**1.96**	**2.05**	**2.49**	**4.35**	**1.52**	2.17
a little more	**3.30**	**3.92**	**4.74**	**-**	**2.85**	2.97
train *(ref: discount)*						
unlimited	**-0.60**	-0.53	-0.31	**-0.98**	**-1.19**	-0.22
free peak & wknd	**-0.23**	-0.55	-0.25	-0.61	0.72	-0.02
disc peak & wknd	-0.09	-0.18	-0.58	-0.08	0.77	1.24
BTM unlimited	**-0.44**	-0.43	**-0.80**	-0.25	0.29	0.66
shared car (low. cost)	-0.09	0.17	-0.14	-0.15	-0.56	-0.16
shared bike unlimited	-0.23	-0.29	0.24	-0.26	-0.66	0.83
taxi (0-6 trips/m)	-0.01	-0.03	0.06	-0.06	-0.06	0.19
transferable taxi trips	0.14	0.14	0.10	0.25	0.49	-0.47
CHANGE IN TRAIN USE						
tresholds						
a lot less	**-2.68**	**-2.75**	**-2.68**	**-4.13**	**-1.78**	-3.08
a little less	**-1.34**	**-1.22**	**-1.97**	**-2.29**	-0.67	-2.24
the same	**1.26**	**1.13**	**1.03**	**1.16**	**2.32**	0.69
a little more	**3.46**	**3.22**	**3.26**	**3.90**	**4.52**	3.89
train *(ref: discount)*						
unlimited	**2.08**	**2.79**	1.70	**1.35**	**3.02**	0.51
free peak & wknd	**0.79**	**0.90**	0.52	**1.04**	0.52	1.18
disc peak & wknd	0.40	0.72	0.38	0.30	-0.31	0.47
BTM unlimited	**0.31**	-0.14	0.60	**0.83**	-0.14	-0.71
shared car (low. cost)	-0.10	-0.15	-0.25	0.35	-0.18	-0.32
shared bike unlimited	0.14	0.44	0.02	-0.24	0.38	1.44
taxi (0-6 trips/m)	**0.08**	**0.05**	0.02	0.00	0.03	-0.35
transferable taxi trips	0.17	0.62	0.05	0.00	0.23	-0.50
CHANGE IN BTM USE						
tresholds						
a lot less	**-3.05**	**-2.68**			**-3.34**	0.11
a little less	**-1.67**	**-1.46**	**-2.62**	**-2.86**	**1.83**	1.25
the same	**1.64**	**1.45**	**2.11**	0.09	**2.09**	4.45
a little more	**3.53**	**3.19**	**3.97**	**3.83**	**3.64**	
train *(ref: discount)*						
unlimited	-0.15	-0.74	0.40	0.13	0.12	1.43
free peak & wknd	0.03	-0.08	-0.02	0.34	-0.10	0.58
disc peak & wknd	0.10	0.00	0.54	0.22	-0.40	0.80
BTM unlimited	**1.42**	**1.95**	**1.68**	0.32	**2.01**	1.54
shared car (low. cost)	0.15	0.07	0.16	0.17	0.40	1.54
shared bike unlimited	0.17	-0.03	0.61	0.13	-0.13	-0.62
taxi (0-6 trips/m)	-0.03	-0.03	-0.08	0.00	-0.03	0.33
transferable taxi trips	0.12	0.12	-0.36	0.17	-0.19	-0.67

T=entire sample, C=car, PT=public transport, B=bike

Of all service level attributes varied in the SC experiment, the variation in the train levels seems to have the largest impact on mode change. In particular, this applies to **unlimited train use**, which, as expected, will increase train use of all groups, in particular the two PT oriented mobility styles (Bike+PT and PT+Car). The impact is smallest for the Car mostly group (C). A the same time, travelers say to decrease car use when they have access to unlimited train use, in particular this applies for the Bike+Car and the PT+Car groups. Similar effects, though less strong, are observed for the train level **free peak and weekend travel**. Interestingly, **unlimited train access** decreases BTM use of the Bike+PT group, which suggests that for this group, train is a substitute for BTM. At the same time, it increases BTM use of all other groups, suggesting complementation, that is, BTM is probably used for train access and egress transport. With respect to **unlimited BTM use**, this level (compared to 20% discount) will increase BTM use of all groups, but only to a limited extent of the Bike+Car group. This group indicates that unlimited BTM will increase their train use, suggesting complementary, while BTM decreases train use or most other groups, suggesting substitution. Unlimited BTM use also has the potential to decrease car use, and surprisingly, this impact is largest for the car mostly group (C). **The low cost structure for shared cars** (compared to the high cost structure) has, in addition to increasing shared car use (not shown in table 2), only a relatively small impact: it tends to decrease both private car use and train use, suggesting substitution, while it tends to increase BTM use, suggesting complementation. Effects are limited, which may be related to the relatively small difference in cost structure as varied in this experiment. **Unlimited shared bike**, has, in addition to the expected increase in use of shared bike and decrease of own bike use (both effects not shown in Table 3), a tendency to increase both train and BTM use a little, suggesting supplementation. While on the other hand, it decreases car use a little, suggesting substitution. On the other hand, the number of **taxi trips** has a much larger impact. In addition to increasing taxi use (not shown in the table), it tends to increase train trips suggesting complementation (note that the impact of taxi is expressed per trip, thus the impact of 6 monthly taxi trips is 6*.08=0.48). On other hand, taxi tends to decrease BTM use and to a lesser extent also car use, suggesting substitution.

Car shedding

To examine to what extent MaaS can reduce car ownership, we asked travelers for each offered MaaS bundle whether they were willing to shed one or more cars if they would receive this bundle for free. As explained before, the question was tailored based on the respondent's current situation and results are presented separately for each group. We examined to what extent service attributes influenced these responses, but none of the attributes appeared to have a statistically significant effect. This suggests that shedding a car does not dependent on the MaaS service offered, but is influenced by other factors. Table 4 therefore only presents the overall responses across all presented MaaS bundles. The results for the current car owners indicate that for 83.4% of the offered bundles, they respond that they will not make any changes to their owned cars. Shedding the second car has some more potential (15.1%), while only 1.5% indicates to shed all cars. Lease car riders even have a higher inclination to keep their cars: to 97.2% of the offered MaaS bundles they respond that they still need their lease car. Finally, even more than half of the travelers who currently do not own a car, indicate that they need one or more cars in the future even if they receive the presented MaaS bundle for free. These results suggest that the presented MaaS bundles have a very low potential to reduce car ownership (see also Ho et al. 2020), even if they are handed out for free.

Table 4 – Car shedding

Get rid of car? (car owners)	
No	83.4%
Yes, of my second car	15.1%
Yes, of my only or all my cars	1.5%
Need car in future? (none car owners)	
Yes	38.6%
No need for second car	17.6%
No need for car at all	43.8%
Lease car (lease car owners)	
No need for lease car anymore	2.8%
Still need lease car	97.2%

MaaS adoption

The results presented so far concern potential MaaS impact when all travelers are given a MaaS bundle for free, which may be regarded as a rather radical transport policy that is not very likely implemented. Of interest is therefore the question to what extent travelers will actually adopt the presented MaaS bundle if they have to pay for it and to what extent the service attributes influence this. To answer this question, we examine the results of the estimated logistic regression model presented in Table 5. The estimated **MaaS constant** is negative, indicating a rather low intention to adopt the MaaS bundle representing the lowest service levels for zero costs. Unsurprisingly, the Car mostly group has the lowest purchase intention, and also the purchase intention of PT+Car groups is relatively low. In contrast, the Bike+PT group has the highest purchase intention. Note that potential adoption is rather different between the two groups who use PT the most and highest for the group who currently uses the car less. Comparable to its impact on mode use change, the **two highest train service levels** also have the largest impact on adoption, which is particularly the case for the Bike+PT group. Also consistent with previous results is that **unlimited BTM** is highly attractive for both Car mostly and the PT+Car groups, while it surprisingly decreases the attractiveness of MaaS for the other two groups. Remarkable is the finding that the **low cost structure of shared cars** substantially increases the inclination to adopt MaaS, which is not only the case for the most frequent car users, but also for the group that uses car the least (Bike+PT). Also **shared bike, number of taxi trips**, and **transferability of taxi credits** increase MaaS adoption, although their impacts are rather limited. As may be expected, **price** has a huge negative effect on adoption. Remarkable is the relatively low price insensitivity of the Car mostly group. Both groups who use bike most (Bike+PT and Bike+Car) are the two groups that have the highest inclination to adopt MaaS, but they are also the most price sensitive groups. While the train service levels have the largest impact on the adoption rates of both groups, the Bike+Car group is most affected by shared car and shared bike.

Table 5 – MaaS Adoption Model (logistic regression model)

	Tot.	B+PT	C	B+C	PT+C
constant	**-1.14**	-0.31	**-2.84**	-0.69	**-2.26**
train *(ref: discount)*					
-unlimited	**1.38**	**2.21**	1.07	0.98	**1.53**
-free peak & wknd	**0.79**	**1.42**	1.18	0.35	1.27
-disc. peak & wknd	0.20	0.48	0.49	0.56	-1.27
BTM unlimited	0.12	-0.11	0.82	-0.67	0.78
shared car (low. cost)	**0.43**	0.35	0.54	0.86	0.47
shared bike unlimited	0.12	0.63	0.10	0.81	-0.37
taxi (0-6 trips/m)	0.07	0.05	0.03	0.10	0.03
transferable taxi trips	0.14	0.32	-0.14	0.42	0.40
price (50-425 €/m)	-	-	-0.001	-	-

To give the reader any idea about MaaS bundle adoption rates and how this varies with price, the model is applied to predict the adoption rates of the minimum and maximum MaaS bundles as included in this study. The results are presented in Table 6. These predictions make clear that the adoption rates for the minimum bundle is rather low, even for a low monthly price. There is considerably more interest for the maximum bundle, however, if this bundle is offered at the realistic market price, that is at € 425 per month, less than a quarter of the travelers is willing to adopt this MaaS bundle.

Table 6 – Predicted adoption rates for minimum and maximum MaaS bundle for various prices

	Minimum	Maximum
train	discount	unlimited
BTM	discount	unlimited
shared car	high costs	low costs
shared bike	€1 per ride	unlimited
taxi no. trips / month	0 trips	6 trips
transferable taxi trips	no	yes
€ 50	20%	65%
€ 125	15%	56%
€ 200	11%	46%
€ 275	8%	37%
€ 350	5%	29%
€ 425	4%	22%

IV. CONCLUSION & DISCUSSION

In order to examine the widespread believe that MaaS will contribute to sustainability, this paper presents the results of a stated choice experiment. Respondents were presented various MaaS bundles that varied in transport services included and costs and they responded to a range of questions about changes in mode use, car ownership and MaaS adoption. The results for mode change show that when travelers are given a MaaS bundle for free, most travelers indicate that they do not change their frequency of mode use. Nevertheless, changes are observed which suggest a range of supplementation and substitution effects of the varied transport services. As expected, higher levels of service and lower costs of a particular mode increases the frequency of using that particular mode. In particular unlimited access to train travel and to lesser extent free train travel in peak hours and in weekends as well as unlimited BTM access, has the largest potential in changing mode use. These service levels also play the most important role in decreasing car use, while the cheaper cost structure of shared car and number of included taxi rides only have limited potential to reduce car trips. Taxi, on the other hand, tends to complement train use but tends to substitute BTM use. Overall, these results corroborate earlier insights that public transport should be regarded as the backbone of MaaS. The results also show that the various modality style groups react differently to the same MaaS bundle. Generally, it was found that the groups that currently use a particular mode more often, have a higher inclination to change the use of that mode. For example, the Car mostly and Bike+Car groups were found to be least likely to increase their train use as a result of more inclusive access to trains in the MaaS bundle, while on the other hand, PT+Car group is most likely to increase its train use. On the other hand, the Car mostly group showed a surprisingly high willingness to use BTM more often and reduce their car use due to unlimited BTM access. Another relevant finding (not presented in the table) is that shared car use only significantly increases for the PT+bike group, which is the group that currently uses the car least often and PT most often.

While the mode use results shows that MaaS has potential to change frequency of mode use, it should be noted that this only can be realized if the MaaS bundles are handed out for free, which is a high costs policy and therefore not very likely implemented. If travelers have to pay for MaaS, they have a low inclination to adopt it, which particularly apply to travelers who use car most often. Less than a quarter of all travelers is willing to adopt the high service bundle at a realistic market price, while the interest for low service bundles is even lower. Furthermore, only very low shares of the car owner is willing to shed all their cars, even if they are given a MaaS bundle for free. MaaS only seems to have some potential in shedding second cars. Thus, our results suggest that currently MaaS has a very low potential to reduce car ownership (see alo Ho et al 2020 and Storme et al. 2020). Hence, MaaS currently is not a viable alternative for car ownership for the far majority of car owners. The results further indicate that current PT users, in particular travelers who now mainly use PT and bike, have the highest inclination to adopt a MaaS bundle. We argued in the Introduction that the relatively easy access to car-based modalities, such as shared-cars and taxi, may result in a higher car use of this group. Indeed the results suggest trends in that direction, which applies in particular for an increased use of shared cars.

However, definitive answers to MaaS sustainability contribution cannot be given based on this study. The results are based on a rather small convenience sample (N=204). Hence, the results should be treated with care and mainly signal possibly trends. Given that most travelers do not report any changes with respect to mode change use, much larger and more representative samples are needed to are arrive at more reliable quantitative predictions about changes in behavior. In addition, the results are based on a stated choice experiment, hence, these may suffer from hypothetical bias. Therefore, it is needed to monitor the actual changes in travel behavior when MaaS services are introduced to the market to gain insights in the real impacts of MaaS. The seven MaaS trials that are planned in the Netherlands are likely going to add to this insight.

Despite an overall limited change in mode use, the results also indicate that the use of shared modes can be increased by including them in MaaS bundles. This suggests that MaaS bundles may be used as a mobility management tool in order to stimulate certain travel behavior. Since the results suggest that the level of experience with shared modes and public transport is a good indicator of the willingness to travel more often with these modes and to adopt MaaS, it could be a reasonable approach to give people the opportunity to try out new behavior. MaaS adoption among car users could furthermore be increased if employers would be stimulated to cooperate, because they are in a position to influence the travel behavior of their employees. Providing people with lease cars is frequently found to make people too much car dependent. Alternatively, they could offer MaaS bundles to their employees.

In addition, because the results suggest that MaaS may potentially increase the use of car-based transport, such as shared cars and taxi by the public transport users, policy makers should consider developing policies that limit the uptake of car-based modalities. One possible direction for this may be to implement pricing measures (Willumsen, 2019). MaaS seems to enable building in sophisticated pricing measures defined by time of day, geography and modal efficiency (Hensher, 2017). Providers that are offering services who make use of government provided assets (the road), should then charge their users extra for using car-based modalities. Such policies may become even more urgent in an autonomous car future where car costs are likely to drop.

Overall, the trends reported in this paper, in particular the low MaaS adoption rates among car owners and their unwillingness to shed their cars as well as the potential increase in car use of the PT users, suggest that question marks can be put to the MaaS' contribution to sustainability. This may have many causes such as the unfamiliarity with MaaS, that cars currently simply offer too much value in comparison, that costs for car use and parking are still too low. It may be clear that MaaS still has a long way to before its promised contribution to sustainable can be realized, if ever, which warrants further research into this important topic.

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