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How do I want the city council to spend our budget? Conceiving MaaS from a citizen's perspective … (as well as biking infrastructure and public transport)

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A R T I C L E I N F O

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A B S T R A C T

While several governmental and research efforts are set upon mobility-as-a-service (MaaS), most of them are driven by individual travel behavior and potential usage. However, considering only individuals' preferences carries the risk of neglecting societal benefits going beyond individual travel behavior. This study addresses the valuation of different features of MaaS-services from a social desirability perspective as compared to social investments in biking infrastructure and in public transport, and aims at eliciting trade-offs between different features of such projects. This analysis is conducted on the basis of Participatory Value Evaluation (PVE). In PVE-experiments, individuals select their preferred portfolio of government projects given a constrained public budget and societal preferences for (the impacts of) government projects can be determined based on these choices.

The results show that the population of Rotterdam exhibits a willingness to allocate public resources to all types of investment projects considered in the analysis. However, the willingness to allocate resources to bike infrastructure projects and public transport seems to be higher than the willingness to dedicate resources to MaaS subsidies. Within the different types of MaaS subsidies considered, subsidies aimed at sustainability exhibit a larger social valuation. Strong negative synergies among similar projects exist, signalizing that individuals prefer diversifying the use of public resources across different types of investment projects.

1. Introduction

Mobility-as-a-Service (MaaS) is a hot topic nowadays. The concept is based upon the idea that mobility requirements be no longer fulfilled by owning mobility tools, such as private vehicles, but rather by simply purchasing mobility services to the extent they are required. On-demand services promise a more efficient utilization of resources and facilitate access to mobility tools otherwise reserved for private owners. Hence, MaaS could bridge the gap between public and private transportation (Shaheen and Cohen, 2013; Jittrapirom et al., 2017; Goodall et al., 2017).

Currently, MaaS-services are in a crucial development stage, and major governmental and research efforts are set upon their implementation (Smith et al., 2018; Yan et al., 2019; Basu and Ferreira, 2020). However, most of these are driven from the perspective of individuals' usage and travel demand aiming at the development of business models. This approach is likely to overlook that the societal value of MaaS-services may differ from the sum of private preferences, as it occurs with the provision of public transport. Therefore, some scholars argue that this may be a too narrow perspective when evaluating governmental projects since choices individuals make in a private setting might not accurately reflect their preferences towards public policy e.g. Ackerman and Heinzerling (2004); Sagoff (1988); Mouter et al., 2018). Hence, certain MaaS-services or ways to conceive on-demand mobility may eventually be deemed as uninteresting and not worth being explored when considered from the perspective of the users,

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even though they are highly valued by society. For instance, even when complementing evaluations based on private behavior with well-established non-monetary costs/benefits (e.g. congestion, emissions, etc.), the assessment is likely to be short-handed, as MaaS offers possibilities whose social desirability is a big unknown and can be hardly captured from a users' perspective only (e.g. enhancing the mobility of the elderly and the poor, complementing public transport, discouraging the purchase of private vehicles, etc.; Kamargianni and Matyas, 2017). Consequentially, it is highly relevant to understand not only users' preferences but also how they relate to the value that society as a whole ascribes to the development of MaaS-services.

The primary goal of this study is to consider the social desirability of MaaS projects, setting the focus on how different possible ways to implement MaaS are evaluated by the population. Along these lines, we also aim at analyzing the societal preferences for the allocation of public resources to MaaS contrasted with allocating public means toward the improvement of the bicycle infrastructure network and the public transport system (and the future of such projects). In addition to that, we aim at addressing and establishing the trade-offs between different features of such projects.

To this end, the preferences of citizens of Rotterdam (the Netherlands) are considered by means of a Participatory Value Evaluation (PVE) - i.e. not evaluating individuals' private choices, but the way in which they would allocate scarce public resources (by selecting investment portfolios consisting of different investment projects) if they were faced with the task of allocating a limited public budget (Mouter et al., 2021a).

The remainder of the paper is organized as follows: Section 2 presents a review of the existent literature, while Section 3 discusses the experimental design and the data collection. Section 4 introduces the modeling framework to be considered in this work and Section 5 presents the results of the model estimation and offers a brief discussion for the purposes of policy-making. Finally, Section 6 presents the conclusions of our study.

2. Literature review

2.1. Participatory Value Evaluation

As previously outlined, this study is based upon Participatory Value Evaluation (PVE). The essence of PVE is that citizens are effectively put in the shoes of a policymaker (Mouter et al., 2021b). This way, the participants of the experiment are expected to provide answers that reflect not only their personal utility maximization processes, but also include their societal preferences (Mouter et al., 2021a). Such preferences may deviate from choices made taking solely the individuals' personal behavior into account. To exemplify this issue, let's consider the provision of infrastructure for individuals with physical disabilities. The large majority of individuals will not make use of this; however, a large share of the population is still might support the allocation of public budget to this cause even if they do not use it. This phenomenon is empirically demonstrated by the fact that such infrastructure exists (in fact, when taking only user's preferences into account, providing such infrastructure would never be deemed socially rentable).

The existence of the aforementioned dichotomy between individual's and group's choices (a consumer/citizen duality according to Mouter et al., 2018) was already described by Buchanan (1954) more than 70 years ago. However, it was not operationalized for the purposes of policy-making up until recent years (Mouter et al., 2021a).

From a practical perspective, a PVE experiment is conducted by means of an online environment, in which the participants (usually common citizens) are faced with: i) which policy options the government is considering; ii) the impacts of the options among which the government can choose, and iii) the constraint(s) that the government faces. Subsequently, citizens are asked to provide a recommendation to the government in terms of the policy options the government should choose, subject to the constraint(s). Since the work by Mouter et al. (2018a), several PVE experiments have provided evidence regarding the existence of the dichotomy in different fields, such as health (Mulderij et al., 2021; Rotteveel et al., 2022), climate policy (Itten and Mouter, 2022), urban mobility (Mouter et al., 2021a), COVID-19 prevention measures (Mouter et al., 2021b), flood protection (Mouter et al., 2021c), among many others.

PVE results can be directly used to consider which possible investment projects are favored by a majority of the population, and so, to derive simple policy advice (e.g. Mouter et al., 2021a; Rotteveel et al., 2022). However, this requires that the projects presented to the individuals be exactly the same projects being considered by the government. This, in turn, can exacerbate well-established biases associated with stated-preference methods (such as strategic answers, among others; Lu et al., 2008). Alternatively, by applying statistical techniques, PVE can be used to derive societal trade-offs between the features of investments projects (e.g. the willingness-to-pay for certain attributes), which could be used to evaluate projects that have not been directly considered by the respondents (akin to customary methods used for cost-benefit analysis – CBA; Boardman et al., 2017). However, up until now, no evidence reported in the literature has followed the latter approach. Nevertheless, common to both approaches is that the results may deviate from the policy-advice derived from CBA (based on individuals' preferences), see Mouter et al. (2021a). Hence, PVE can be understood as complementary to an evaluation based purely on private preferences, as it incorporates additional elements from the political decision process.

Two methodological approaches have been reported in the literature to model PVE-choices. First, Dekker et al. (2019) introduce a framework based upon the multiple discrete-continuous extreme value (MDCEV) model (Bhat, 2008). While this framework promises statistical efficiency, its main limitation is that the utility of each portfolio is assumed to be equal to the sum of the utility of the projects that comprise it (it is not straightforward to lift this limitation within the MDCEV framework, as errors are considered at the project level only). In order to take synergies among projects into account, Bahamonde-Birke and Mouter (2019) proposed an alternative modeling approach that requires fully enumerating all combinations of feasible portfolios, moving the error terms to the portfolio level. This comes with the caveat that additional error terms (at the project level) have to be introduced to capture the correlation among portfolios comprising the same projects, which, in turn, comes at the expense of computational efficiency.

2.2. Projects' features

This study addresses three different kinds of investment projects, namely subsidizing MaaS, improving the infrastructure of the bicycle network, and improving the provision of public transport. While none of these subjects have been previously addressed by means of PVE (at least, as reported in the literature), numerous studies on each of the subjects have been conducted by means of discrete-choice experiments (DCE) based on individuals behavior.

The demand for MaaS is a highly complex subject, as MaaS-subscriptions can include a very large number of dimensions, including transportation modes (car-sharing, bike-sharing, public transport, taxi, shared-scooters, etc.), payment system (unlimited use, discounted prices, etc.), charging system (per time unit, per trip, etc.), among many others (Bahamonde-Birke et al., 2023). In the context of DCEs, MaaS is customarily represented using bundles (Matyas and Kamargianni, 2019; Guidon et al., 2020; Ho et al., 2020, etc.). While most (but not all) studies typically rely upon only one charging scheme and only one payment scheme, to the authors' best knowledge, all MaaS-bundles reported in the literature include at least four transportation modes. Public transport, car-sharing, and bike-sharing are almost ubiquitously considered; other modes that are usually considered are taxi, shared-scooters, and shared e-bike. The reader is referred to

Reck et al. (2020) for a good discussion on the construction of MaaS-bundles.

The biking infrastructure has also been addressed by multiple studies. The most common setup shows choices between different kinds of bike lanes (Rossetti et al., 2019; Hardinghaus and Papantoniou, 2020; among many others), but other setups, such as preferences for different types of roundabouts (Poudel and Singleton, 2022), route choices (Livingston et al., 2019), residential locations (Bahamonde-Birke et al., 2017), and the decision whether to cycle or not (Akar and Clifton, 2009), etc., have also been reported in the literature. Regarding the infrastructure, common to most studies is that individuals prefer cycle lanes segregated from both automobiles as well as pedestrians. Also, in several studies (e.g. Rossetti et al., 2019; Poudel and Singleton, 2022) bicycle users favor segregated lanes at street level (favoring the integration into the traffic flow). This kind of bike lane, however, is uncommon in the Netherlands, where most bike lanes are either not segregated (*fietsstrook*) and at street level, or fully segregated and at sidewalk level (*fietspad*). Also, other kinds of bike lanes exist that are characterized by very few intersections and are usually implemented along highways, waterways (quite common in the Netherlands), and parks (these kinds of lanes are known as *solitair fietspad* and *fietssnelweg*).

Improving public transport systems is one of the main fields of study in transportation, and consequentially several alternatives have been proposed to do so. In the context of this study, it was decided to address alternatives that the city considers research priorities, given the lack of empirical research in this regard, namely the expansion of feeder shuttle services (driving individuals to/from metro and train stations) and the implementation of shared-mobility hubs. While the former has received moderate attention in the literature (Deka et al., 2010; Yan et al., 2019), most studies consider the provision in the context of mode choices only (considering standard transportation attributes, such as cost, travel time, waiting time, and access time). On the other, the impact of shared-mobility hubs has received very limited attention in the literature (Tran and Draeger, 2021).

3. Experimental design

This study was conducted in several stages. First, a set of feasible and attractive transport and mobility investment projects was identified in cooperation with the city of Rotterdam.

In order to address the willingness of the population to allocate resources to MaaS, it was assumed that two different MaaS subscription packages (a small and a large subscription) were available to the public. Each one of these subscription packages was described in terms of the price paid by the users as well as the number of trips by public transport, the number of trips by bike-sharing, free hours of car-sharing, and the number of trips by taxi included in the package. Additionally, both subscription packages (small and large) were differentiated by the type of uses: a regular offer and a discounted (and eventually improved) offer for the so-called "social group" consisting of elderly (above the retirement age) and individuals with physical disabilities. The discounted subscription for the social group also included some specific features (e.g. free public transport, as nowadays in Rotterdam the use of public transport is free for the elderly population). The subscription packages were constructed in such a way that they align with current prices paid in Rotterdam for shared services and public transport. Similarly, the constitution of the packages reflects the general guidelines discussed in the planning consultation meetings of the 7 National MaaS pilots to be implemented throughout the Netherlands (Ministerie van Infrastructuur en Waterstaat, 2019).

All possible MaaS investment projects considered a subsidy that would affect the monthly costs of the subscriptions as well as some key attributes of the packages. MaaS subsidy projects targeting the general population would simply reduce the monthly fee paid by all individuals. Projects aimed at the elderly and socially disadvantaged would only reduce the monthly fee paid by the social group, while also focusing on features that are likely to be used by them (e.g. taxi services would be improved for the social group only). Finally, MaaS subsidies aimed at sustainability would focus on features such as the integration of MaaS with public transport and bike-sharing. The social costs of the MaaS investment projects were presented as the total cost of the subsidies over a period of five years. All projects also include the number of users that would use MaaS with and without the subsidy, disaggregated by regular users and members of the social group (older individuals as well as individuals with physical disabilities).

Fig. 1 represents the way in which MaaS investment projects were presented. On the left, we have the small (*MaaS Abo S*) and large (*MaaS Abo* L) subscription packages without subsidies. Each of them includes a regular offer (within each subscription package on the left) and a discounted (and eventually improved) offer for the social group (within each subscription package on the right). Below, the number of users (*Gebruikers MaaS*) is indicated (*Volwassen* stands for regular users and *Sociale doelgroep* for the social group). On the right, we have the situation after the project has been implemented. The changes are shown in red (in this case, a general subsidy diminishing the costs for everyone is presented). In this example, the cost of the subsidy amounts to 5.8 MM € (5.8 million euros).

Investments in MaaS were contrasted with possible investments in bike infrastructure and in public transport. The former were defined in terms of the expansion of the current infrastructure, focusing on six key aspects: kilometers of non-segregated on-street bike lanes (*fietsstroken*), kilometers of fully-segregated bike lanes at street level (*gescheiden fietspaden op straatniveau*), kilometers of fully-segregated bike lanes at sidewalk level (*gescheiden fietspaden op stoepniveau*), kilometers of bike-freeways (*solitair fietspad/fietssnelweg)*, number of improved bike-crossings in the city center (*verbetering drukke oversteekpunten*), the number of available spots in public bicycle parking stations (*fietsstallingen*), as well as the costs over a period of 5 years. The first five features were accompanied by graphic representations and images to clearly illustrate the different kinds of bike lanes and improved bike-crossings. Fig. 2 shows how the different bike investment projects were presented to the respondents (the representation follows the same logic as Fig. 1) (see Fig. 3).

Finally, public transport projects were described in terms of the reduction of the average access distance to bus stops (*gemiddelde afstand tot een bushalte*), the number and frequency of shuttle lines connecting suburbs with the metro and train system (*aantal shuttle-verbindingen in netwerk* and *frequentie*, respectively), and the number of public transport mobility hubs (understood as multi modal stations oriented towards the integration of public transport and other mobility options). Again, the costs were presented as the total costs in five years.

As a second step, a qualitative phase was conducted to identify the decision-making process of citizens and obtain insight into their preferences and the way they would allocate public budgets to different investment portfolios (i.e. which triggers motivate citizens to opt for a given project or combination of projects). For this purpose, interviews with different citizens from Rotterdam were conducted. In total, 12 interviews were conducted. Participants were invited by post (addresses were randomly drawn). The selected sample exhibited the desired variability in terms of gender, age and socio-demographic background.

Among the main insights gained from this phase, it is important to name that the complexity of the experiment had to be reduced. Therefore, from this point on each respondent was confronted with 3 MaaS projects, 2 biking infrastructure projects and 2 public transport projects (down from 12 projects in total). Furthermore, some individuals (not all) wanted to allocate resources to projects based on their general goals and description, rather than on their particular attributes. It was also possible to identify a clear willingness to distribute resources among different kinds of projects (i.e. to spread the budget between MaaS, biking and PT projects) and to exhaust the budget.

Finally, the PVE experiment was carried out by means of an online survey. Each respondent was faced with three different choice-tasks,

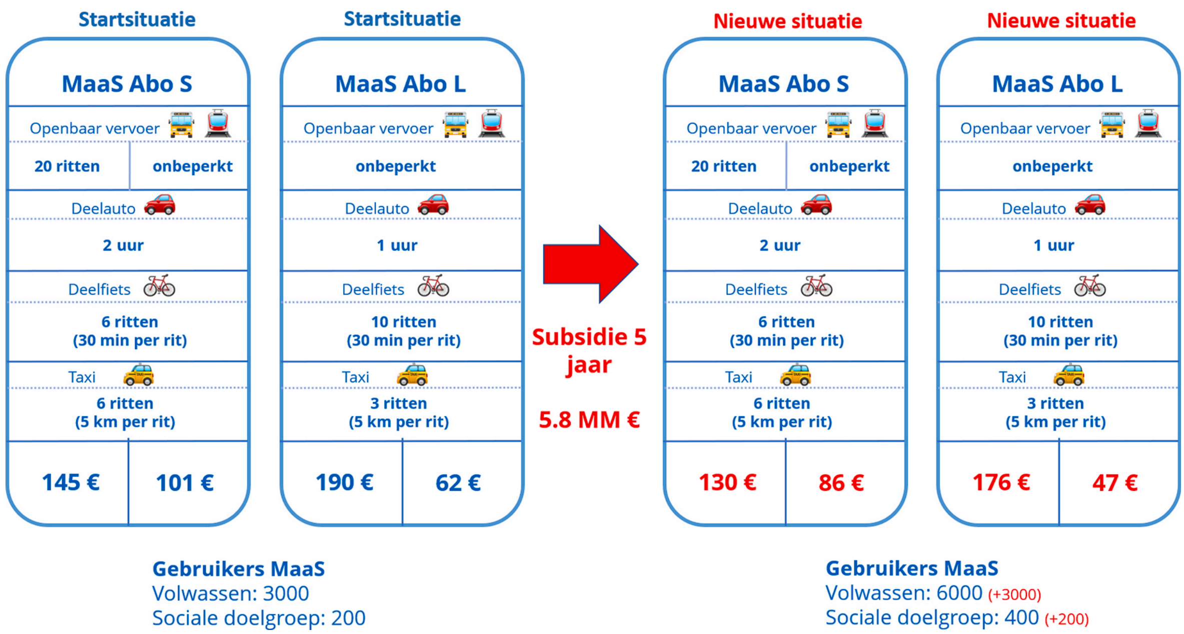

Fig. 1. Example of a MaaS subsidy project.

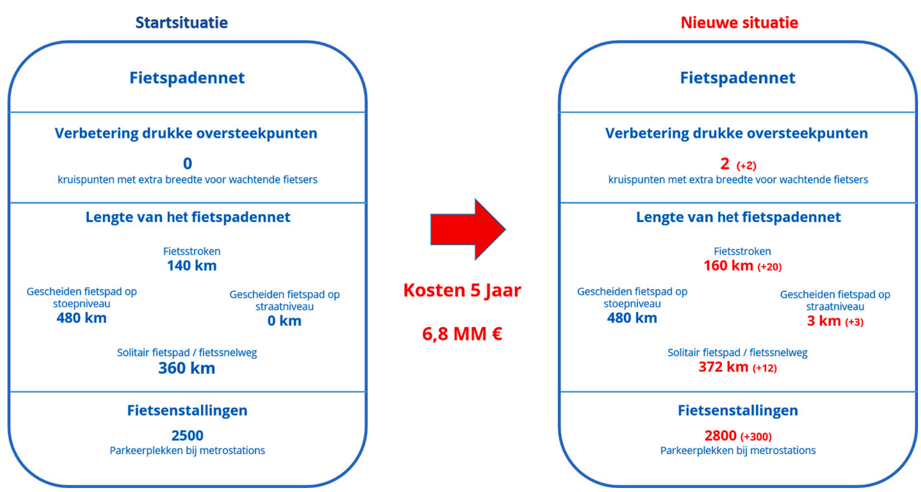

Fig. 2. Example of a biking infrastructure project.

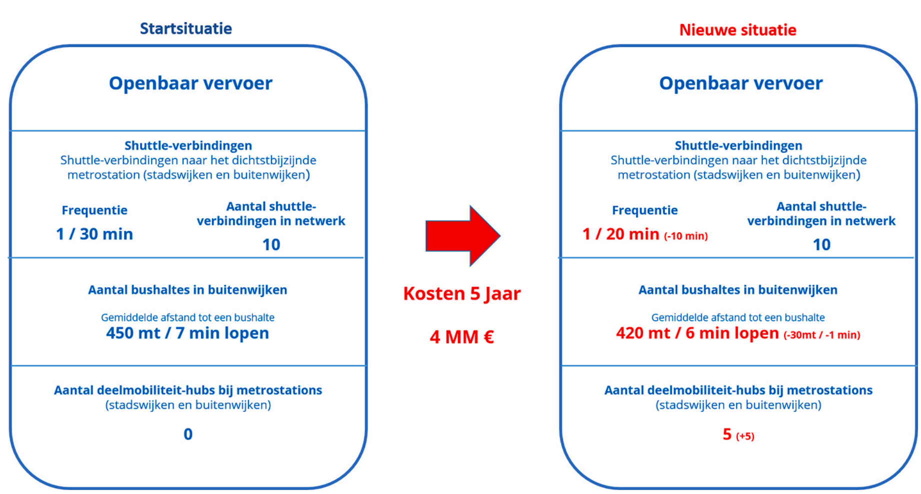

Fig. 3. Example of a public transport project.

stating their preferences under 3 different budgets (15 MM €, 20 MM €, and 25 MM €, presented in random order). Although the total available budget varied, the features of the projects faced by the same individual remained the same to avoid overwhelming the respondents. The features of the projects themselves were randomly drawn from a pool of 27 choice-scenarios. These were carefully designed to avoid dominance and exhibit enough variability to allow for the estimation of the models. As previously mentioned, each respondent was confronted with seven different projects. As more than one project (or even none) can be selected, it leads to $2^7 = 128$ possible combinations of projects. However, due to the budget limitations, no respondent faced more than 96 feasible portfolios (combinations of projects) under the highest budget (the number of feasible portfolios depends on the costs of the projects in the different scenarios).

The survey was carried out in the last semester of 2021. Households from the entire city were randomly selected and contacted by post. In total, ca. 10,000 invitations were distributed and more than 500 individuals answered the survey (response rate ca. 6%, as a significant proportion of the letters came back as undeliverable), which led to more than 1500 observations. However, after data cleansing, only 410 responses (1230 observations) were considered suitable for modeling purposes.

The sample exhibits a bias in terms of socio-demographic indicators, especially in terms of gender and educational level (see Appendix 1). Consequently, it is important to control for those variables when estimating the models.[1]

4. Methodological framework

As the qualitative analysis clearly showed, individuals preferred varied portfolios to allocate resources to different types of investments. Hence, it was to take (negative) synergies into account (namely, that the whole utility of a portfolio may differ from the sum of the utilities of the projects that make up that portfolio), it was decided to analyze the data relying upon the PVE portfolio approach (Bahamonde-Birke and Mouter, 2019). Furthermore, given that the individuals were confronted with 3 MaaS projects, 2 biking infrastructure projects, and 2 public transport projects, it was also necessary to take correlation into account, which is also facilitated by the flexibility of the PVE portfolio approach.

Under this framework, it is assumed that the decision-maker i would select the portfolio p if and only if its expected social utility SU_{ip} is larger than the social utility of any other portfolio belonging to the set of feasible portfolios A_{ip}. Hence, the choice probability of the portfolio p is given by:

$$\Pr_{ip} = \Pr\left(SU_{ip} > SU_{iq}\right) \forall p \neq q \in A_{ip} \quad [1]$$

At the same time, and assuming additive linearity, the social utility of any given portfolio will be given by the sum of the expected social utility SU_{ik} of each of the k projects that make up the portfolio, plus synergy terms $\alpha_{k1} \ldots \alpha_{km}$ (representing the synergies between project k and projects 1 … m, and consequently that the utility of the portfolio may be more or less than the sum of its parts) and the valuation of the unexhausted budget (represented as the difference between the budget B and the sum of the costs C_k associated with the projects k belonging to p). Finally, as previously mentioned, the portfolio approach considers error terms ε_{ip} at the level of the portfolios (which is necessary as the synergies exist at portfolio level). Hence, the social utility of a portfolio SU_{ip} can be represented as:

$$SU_{ip} = \sum_{\forall k \in p} SU_{ik} + \sum_{\substack{\forall k \in p \\ \wedge m \neq k \in p}} \alpha_{km} + \alpha_B \cdot \left(B - \sum_{\forall k \in p} C_k\right) + \varepsilon_{ip} \quad [2]$$

Finally, the social utility SU_{ik} associated with each project can be expressed as a function of the project's features and of the characteristics of the decision-maker i. Again, if we assume additive linearity, SU_{ik} can be expressed as:

$$SU_{ik} = \beta_k + \sum_j \beta_{kj} \cdot x_{ikj} + \eta_{ik} \quad [3]$$

where β_k represents the project-specific constant (PSC) and β_{kj} the marginal social utility of the project's features and the individual's characteristics x_{ikj}. Finally, η_{ik} is an error term that can follow any desired distribution and represents any measurement error at the level of the projects' utilities. Consequently, η_{ik} allows taking into account that different portfolios comprising the same projects are likely to exhibit stochastic correlation. Along these lines, it is also possible that the social utility of the projects themselves also exhibit stochastic correlation (e.g. in our case, the utility of both bike infrastructure projects likely exhibit stochastic correlation); in that case, η_{ik} can simply be expressed as the sum of an independent project- and individual-specific error term and another individual-specific error term, common across both projects (representing thus the stochastic correlation).

Assuming that the error terms ε_{ip} are i. i.d. EV1-distributed leads to a Multinomial Logit (MNL) model at the level of the portfolios (Domencich and McFadden, 1975). The error terms at the project level, however, need to be considered via mixing. Consequently, the results are to be considered by means of Mixed Logit (ML) models (Cardell and Dunbar, 1980; Boyd and Mellman, 1980) and the choice probabilities are to be computed by integrating over the domain of the error terms η_{ik}. Furthermore, as each individual provided more than one answer t (under different budgets B_t), the answers by the same respondents are likely to be correlated. Hence, the integrals have to be calculated at the level of the individuals (i.e. assuming that the error terms remain constant for all answers provided by the same individual). Under these circumstances the likelihood function associated with the answers at the portfolio level takes the following shape:

$$L = \prod_i \int_s \prod_t \prod_p P\left(y_p = 1 \middle| x_{ikj}, B_t, C_k, \eta_k; \alpha_{k\ldots m}, \alpha_B, \beta_k, \beta_{kj}, \Sigma_{\eta_k}\right)^{y_p} \cdot d\eta_k \quad [4]$$

Where y_p is a dichotomous variable taking a value of 1 if a given portfolio is selected and zero otherwise and P (%) represents the MNL probability kernel. Maximizing eq. (4) allows estimating $\alpha_{k1} \ldots \alpha_{km}$, α_B, β_k, β_{kj}, and $\Sigma_{\eta k}$.

5. Results and discussion

The section reports the results of the model estimation. All features of the alternatives as well as the socio-demographic characteristics of the individuals were considered (although not all of them were found to have a statistically significant impact on the results). Table 1 introduces the estimators (and indirectly the variables) that were found to have a statistically significant impact on the outcome, as well as political variables that were kept in the model for illustrative purposes despite not having a statistically significant impact. It was controlled for biased attributes of the sample via interactions with the project features (see Table 2).

As can be observed, not all variables introduced in Section 3 were considered in the final model. In the following, we present the results of the model estimation. The utility functions were considered to be Linear in Parameters with Added Disturbances (LPAD) with simulated random

[1] Note that as we are considering disaggregated models, a biased sample does not imply a biased model as long as it is controlled for the biased attributes.

Table 1
Definition of the estimators considered in the model.

Variable	Definition
PSC MaaS 1	Project specific constant of MaaS subsidy projects targeting the general population.
PSC MaaS 2	Project specific constant of MaaS subsidy projects targeting the social group.
PSC Maas 3	Project specific constant of MaaS subsidy projects targeting sustainability.
PSC Bike	Project specific constant of both bike infrastructure projects (both project are unlabeled).
PSC PT	Project specific constant of both public transport projects (both project are unlabeled).
ß MaaS 2 × Ed. High	Group-specific valuation of MaaS subsidy projects targeting the social group by highly-educated individuals (bachelor-degree or higher) opposite to the rest of the population
ß MaaS 2 × Old	Group-specific valuation of MaaS subsidy projects targeting the social group by old individuals (65 years or older) opposite to middle-aged individuals (35–64 years).
ß MaaS 2 × Young	Group-specific valuation of MaaS subsidy projects targeting the social group by young individuals (18–34 years) opposite to middle-aged individuals (35–64 years).
ß PT × Ed. High	Group-specific valuation of public transport projects by highly-educated individuals (bachelor-degree or higher) opposite to the rest of the population
ß MaaS users	Marginal social utility of the number of regular users of MaaS.
ß MaaS users (social group)	Marginal social utility of the number of users of MaaS belonging to the social group.
ß bike-crossing	Marginal social utility of the number of improved bike-crossings in the city center.
ß bike-parking	Marginal social utility of the number of available spots in public bicycle parking stations.
ß bike-lane street-level	Marginal social utility of the kilometers of fully-segregated bike lanes at street level.
ß bike-lane sidewalk-level	Marginal social utility of the kilometers of fully-segregated bike lanes at sidewalk level.
ß bike-freeway	Marginal social utility of the kilometers of bike-freeways.
ß distance bus-stop	Marginal social utility of reducing of the average access distance to bus stops by 1 m.
ß budget	Marginal social utility of the unexhausted budget.
ß synergy MaaS 1 & MaaS 2	Synergy between MaaS subsidy projects targeting the general population and the social group.
ß synergy MaaS 1 & MaaS 3	Synergy between MaaS subsidy projects targeting the general population and sustainability.
ß synergy MaaS 2 & MaaS 3	Synergy between MaaS subsidy projects targeting the social group and sustainability.
ß synergy Bike	Synergy between both bike infrastructure projects.
ß synergy PT	Synergy between both public transport projects.
η error term MaaS 1	Standard deviation of the project specific error term associated with MaaS 1.
η error term MaaS 2	Standard deviation of the project specific error term associated with MaaS 2.
η error term MaaS 3	Standard deviation of the project specific error term associated with MaaS 3.
η correlation MaaS	Standard deviation of the stochastic correlation among all MaaS projects.
η error term Bike 1	Standard deviation of the project specific error term associated with Bike 1.
η error term Bike 2	Standard deviation of the project specific error term associated with Bike 2.
η correlation Bike	Standard deviation of the stochastic correlation between both Bike projects.
η error term PT 1	Standard deviation of the project specific error term associated with PT 1.
η error term PT 2	Standard deviation of the project specific error term associated with PT 2.
η correlation PT	Standard deviation of the stochastic correlation between both PT projects.

Table 2
Model results.

Variable	Equation	Estimator	Standard deviation	t-statistic
PSC MaaS 1	Project level: MaaS 1	**0**	*fixed*	(–)
PSC MaaS 2	Project level: MaaS 2	**0.139**	*0.6*	(0.232)
PSC Maas 3	Project level: MaaS 3	**0.48**	*0.267*	(1.79)
PSC Bike	Project level: Bike 1, Bike 2	**0.313**	*0.454*	(0.689)
PSC PT	Project level: PT 1, PT2	**1.52**	*0.31*	(4.92)
ß MaaS 2 × Ed. High	Project level: MaaS 2	**−2.23**	*0.497*	(-4.48)
ß MaaS 2 × Old	Project level: MaaS 2	**1.63**	*0.595*	(2.74)
ß MaaS 2 × Young	Project level: MaaS 2	**−0.934**	*0.494*	(-1.89)
ß PT × Ed. High	Project level: PT 1, PT2	**−0.785**	*0.255*	(-3.08)
ß MaaS users	Project level: MaaS 1, MaaS 2, MaaS 3	**2.89E-05**	*6.84E-05*	(0.423)
ß MaaS users (social group)	Project level: MaaS 1, MaaS 2, MaaS 3	**0.00017**	*0.000353*	(0.481)
ß bike-crossing	Project level: Bike 1, Bike 2	**0.0591**	*0.0169*	(3.5)
ß bike-parking	Project level: Bike 1, Bike 2	**0.000409**	*0.000122*	(3.35)
ß bike-lane street-level	Project level: Bike 1, Bike 2	**0.0501**	*0.0262*	(1.91)
ß bike-lane sidewalk-level	Project level: Bike 1, Bike 2	**0.0694**	*0.0366*	(1.89)
ß bike-freeway	Project level: Bike 1, Bike 2	**0.0422**	*0.0286*	(1.48)
ß distance bus-stop	Project level: PT 1, PT2	**0.00435**	*0.00142*	(3.07)
ß budget	Portfolio level	**−0.364**	*0.0412*	(-8.85)
ß synergy MaaS 1 & MaaS 2	Portfolio level	**−0.684**	*0.338*	(-2.02)
ß synergy MaaS 1 & MaaS 3	Portfolio level	**−0.153**	*0.266*	(-0.574)
ß synergy MaaS 2 & MaaS 3	Portfolio level	**−0.305**	*0.276*	(-1.11)
ß synergy Bike	Portfolio level	**−1.59**	*0.283*	(-5.64)
ß synergy PT	Portfolio level	**−0.886**	*0.245*	(-3.61)
η error term MaaS 1	Project level: MaaS 1	**2.57**	*0.305*	(8.42)
η error term MaaS 2	Project level: MaaS 2	**3.02**	*0.377*	(8)
η error term MaaS 3	Project level: MaaS 3	**2.06**	*0.258*	(7.98)
η correlation MaaS	Project level: MaaS 1, MaaS 2, MaaS 3	**1.15**	*0.321*	(3.58)
η error term Bike 1	Project level: Bike 1	**1.29**	*0.292*	(4.43)
η error term Bike 2	Project level: Bike 2	**1.18**	*0.297*	(3.97)
η correlation Bike	Project level: Bike 1, Bike 2	**2.56**	*0.245*	(10.4)
η error term PT 1	Project level: PT 1	**1.79**	*0.211*	(8.5)
η error term PT 2	Project level: PT2	**0.925**	*0.38*	(2.44)
η correlation PT	Project level: PT 1, PT2	**1.28**	*0.252*	(5.1)
Log-likelihood	**−3218.58**			
Equiprobable Log-likelihood	**−4557.83**			
ρ2	**0.294**			
Number of parameters	**32**			
Number of observations	**1230**			

disturbances (independent and correlated) at project level and error terms (i.i.d. EV1-distributed) at portfolio level. All random parameters considered via simulation were assumed to be normally distributed. All models were estimated making use of Biogeme 3.2 (Bierlaire, 2020). To compute the likelihood function, 2000 MLHS draws were utilized (Hess et al., 2006).

The results show that, in general terms, bike infrastructure and public transport investment projects are better evaluated than MaaS subsidies. While the PSC associated with the bike infrastructure projects is not statistically significant, most project features of the bike infrastructure projects do have a statistically significant positive outcome. This (in conjunction with none of the features of MaaS projects being significant), implies that the valuation of bike projects is necessarily higher.

However, the willingness to allocate resources to MaaS is far from negligible and portfolios comprising them exhibit a considerable choice probability. Within MaaS alternatives, individuals substantially prefer subsidies aimed at sustainability. Subsidies favoring the elderly and the handicapped are poorly evaluated by young and by highly educated individuals. Older individuals, in turn, ascribe a higher social utility to them. A possible explanation for this phenomenon is that the elderly would directly profit from such a subsidy. While it is possible to identify a willingness to allocate resources to the general goals pursued by different MaaS projects (namely subsidies for the general population, social groups, and sustainability), no significant effect could be associated with the features of such projects. The latter is most likely related to the complexity of the tasks (a phenomenon already identified during the qualitative analysis). Also, a statistically significant stochastic correlation among the social utility ascribed to the three MaaS projects was identified.

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Within biking infrastructure projects, it was possible to establish that non-segregated on-street bike lanes do not seem to affect the willingness to allocate resources to a given project. In turn, fully-segregated bike lanes at street level, fully-segregated bike lanes at sidewalk level, and bike-freeways all exhibit a positive and similar valuation (no statistically significant differences among them can be identified). This is an interesting result as fully-segregated bike lanes at street level are uncommon in the Netherlands and non-existent in Rotterdam. Furthermore, the social utility ascribed to improved bike-crossings in the city center does not statistically differ from the social utility of one additional kilometer of the aforementioned bike lanes, and roughly amounts to the utility of 100–150 spots in public bicycle parking stations (which is also positive and significant). The valuation of biking infrastructure projects is strongly correlated.

When considering public transport projects, it was observed that neither the number or frequency of shuttles nor the number of mobility hubs had any significant impact on the valuation of the portfolios. Reducing the average access distance to bus stops, in turn, proved highly significant. The social value of a reduction of 10 m in average roughly amounts to the social utility ascribed to 0.8 km–1.0 km. Of cycle paths (these results, however, must be carefully considered as it is harder for the respondents to compare the features of projects of substantially different nature, e.g. public transport and biking infrastructure). These results, in association with the willingness to allocate resources (in general) to public transport investment projects and in conjunction with insights gained during the personal interviews, show that individuals are willing to allocate resources to public transport even when some of the features presented to them (namely mobility hubs or shuttle services) do not seem to be particularly attractive.

Also, very strong negative synergy effects were identified between both bike infrastructure projects, between both public transport projects, and between the MaaS projects subsidizing the general population and the social group. It shows that individuals strongly prefer to distribute the budget among different kinds of investment projects, which fully aligns with the findings by Bondemark et al. (2022). Interestingly, there are no statistically significant synergies between either project MaaS 1 or Maas 2 and a MaaS subsidy targeting sustainability. A possible explanation is that the motivations for allocating resources to the latter may differ from the motivations behind a general subsidy for MaaS.

Finally, the budget parameter exhibits a negative sign, which means that individuals seek to extenuate their allocated budget.

6. Conclusions

The social valuation of public investment projects does not necessarily align with the valuation based on individual behavior, as individuals may consider projects to be socially desirable (or undesirable) even if these (societal) preferences do not align with their use or behavior. Against this background, and given the crucial stage of development of MaaS in the Netherlands and in the world, this study addressed the willingness of the population to allocate public means to different features of MaaS from a perspective of social desirability as compared with alternative public investment projects and their features. By means of PVE, projects subsidizing MaaS were contrasted with bike infrastructure projects and improvements of public transport.

The results allow establishing the social utility that the individuals ascribe to the different investment projects considered in the study. Along this line, it is also possible to calculate the marginal social utility of the projects' features and to elicit trade-offs among them. Direct takeaways from a policy perspective are that the city may explore the introduction of fully-segregated bike lanes at street level, where other alternatives are not feasible (as all kinds of segregated bike lanes are valued similarly). Similarly, dedicating resources to non-segregated on-street bike lanes should be reconsidered given the poor valuation associated with this kind of bike lanes. Furthermore, social valuation trade-offs for improved bike-crossings and bike parking facilities have been derived, which can be used to enhance the social evaluation of projects.

Also, the results show a strong preference for diversifying the investments among different types of mobility projects. MaaS subsidies aimed at sustainability, however, do not exhibit negative synergies with any other type of investment project; hence, they can be added to any investment portfolio without majorly affecting the utility ascribed to the other projects in the portfolio. Along these lines, this kind of subsidy exhibits the highest social utility of all kinds of MaaS subsidies, making it an attractive option to evaluate first if resources are to be allocated to MaaS. Finally, among the public transport features evaluated in this project, the one associated with the highest social utility seems to be reducing the average access distance to bus stops.

It is important to remark that, while individuals exhibit preferences for different types of MaaS subsidies (in terms of their general description and their goals), these valuations did not translate into a distinctive valuation of the features of the MaaS investment projects. The latter is probably due to the high complexity of MaaS bundles (as shown during the qualitative analysis). Consequently, while it is possible to identify preferences to guide the development of MaaS towards specific societal goals (particularly sustainability), nothing can be concluded about the specific way in which MaaS bundles should be constructed. Further research is required in this regard. To this end, and given the complexity of the choice task in this experiment, it may be preferable to consider PVE experiments in which only MaaS related investment projects are presented to the respondents. The latter, however, implies that it would not be possible to consider to which extent individuals are willing to allocate resources to MaaS (in general). A two-stage experimental approach (first considering different investment topics and then projects with similar features) may overcome this issue. Further research is also needed concerning this matter.

Data availability

The data is under embargo and will be made avalaible as soon as possible

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APPENDIX 1

Descriptive statistics of the participants

Variable	Frequency
Male	*257*
Female	*153*
18-34 years	*156*
35-64 years	*168*
+ 64 years	*66*
Higher education	*308*

(*continued on next page*)

(*continued*)

Variable	Frequency
Not-higher education	*102*
Low Income (< 29,100€)	*136*
Medium Income (29,100€-54,800€)	*156*
High Income (> 54,800€)	*118*

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