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Public support for tradable peak credit schemes

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ABSTRACT

Congestion charging is generally regarded as an effective tool to manage the ongoing growth in road use and to abate congestion. However, public support is typically very low and therefore very few charging schemes have been implemented. The concept of tradable peak credits (TPC), which is based on the cap-and-trade principle, has characteristics that are believed to lead to more public support. First, a TPC system is revenue-neutral since the money circulates within the user group. Also, the expected effectiveness, and thereby support, may be higher because, in a TPC system, the operator has more control over the inflow of cars due to the firm cap. Lastly, the allocation of free credits provides the opportunity to address equity issues. This paper aims to quantify the levels of support for TPC among the public and to explore what the influence of scheme design, personal characteristics and attitudes is on these levels of support. To that end, a stated choice experiment has been conducted in which respondents were asked whether they would vote for the implementation of different TPC schemes. The discrete choice model shows that 32%, and up to a small majority of 52%, would support different TPC schemes. Most people, however, like or dislike TPC regardless of the scheme design. It is attitudes, and to a limited extent also socio-demographics, that relate to someone's level of support, rather than the scheme characteristics. Support is especially higher among people who find TPC fair and effective, who live outside the borders of the municipality and are lower educated. Although the results indicate that a small majority would support a TPC scheme, directions for future research are given to supplement this study.

1. Introduction

The ongoing growth in car use is increasingly threatening the livability and economy of urban areas. Ever since [Pigou's publication \(1920\)](#), many academics from the field of transportation have been studying and promoting the efficiency of congestion pricing solutions to optimise the use of scarce road infrastructure (e.g. [Small and Verhoef, 2007](#); [Vickrey, 1963](#)). A long-standing barrier to the actual implementation of congestion pricing solutions is, however, the typical, strong resistance of the public in general, and car users in particular (see [Vonk Noordegraaf, Annema and van Wee, 2014](#)). Hence, the literature on the support for different congestion pricing solutions and the factors related to supporting (or opposing) these is extensive ([Gaunt, Rye and Allen, 2007](#); [Hamilton et al., 2014](#); [Jaensirisak, Wardman and May, 2005](#); [Schade and Schlag, 2003](#); [Schuitema and Steg, 2008](#); [Ubbels and Verhoef, 2006](#)). In these studies, recurring factors that are found to affect public acceptability negatively involve the expected low effectiveness of the pricing

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Table 1
Overview of tradable credit concepts for mobility management that have been studied regarding public acceptability.

Concept	Targets	Short description	Acceptability studies	Context	Respondents	Method
Tradable Driving Credits (TDC)	Total amount of kilometres driven by car	Free number of car (tradable) kilometres for each individual.	Dogterom et al. (2018a)	The Netherlands and Beijing	Car users	Online survey with rating questions
Credit Based Congestion Pricing (CBCP)	Car trips during peak hours	Free monthly credits for registered car owners. They can exceed their allowance or exchange them for cash.	Kockelman and Kalmanje (2005)	Austin, Texas	Citizens of Austin	Survey (online and on paper) with rating questions
Tradable Peak Credits (TPC)	Car trips during peak hours	Free tradable credits. Who receives them and how often, varies per scheme.	This study	Urban areas in the Netherlands	Citizens in the regions of Amsterdam and Utrecht	Online stated choice experiment with different schemes

solution, the perceived unfairness of the scheme's redistribution of welfare, a distrust in the government's use of the revenues, and the expected increase in travel costs.

Because of these problems, academic interest in the concept of tradable credits¹ as a tool to approach roadway capacity allocation and manage congestion has increased (Buitelaar, van der Heijden and Argioliu, 2007; Grant-Muller and Xu, 2014; Raux, 2008; Raux and Marlot, 2005; Yang and Wang, 2011). The idea to apply the cap-and-trade principle in congestion management is not new (Goddard, 1997; Verhoef, Nijkamp and Rietveld, 1997b; Viegas, 2001), but was not considered by many as a realistic policy option due to high transaction costs, among other things. The rapid developments in technological solutions, such as internet trading and automatic vehicle detection, may have caused the increased amount of academic studies undertaken. Tradable credits for congestion management are still a concept rather than a developed policy that can lead to different scheme design (see Fan and Jiang (2013) for an overview). In this study the basic concept is understood as the following, and is referred to as TPC (tradable peak credits) from here on. The regulator (the government in this study) determines a firm limit, a *cap*, on the total level of car use in a certain area (all roads in the municipality) during a certain time period (peak hours during weekdays) and translates that cap into credits which are distributed among recipients (e.g. citizens or road users) using a specific allocation method every trading period (e.g. week or month). In addition, the regulator creates a market where people can *trade* their peak credits, in which supply and demand set the price of a credit. When car users use the defined area during the defined time period, one credit will be taken from their budget. Also when someone drives on multiple roads during one peak period, this costs one credit. Although most studies on tradable credits for mobility management focus on the effects on traffic flows, the scheme design, or the behavioural responses, they usually state the following advantages that may lead to stronger support for these credits. First, the operator in this type of cap-and-trade system has more control over the number of cars than with a pricing-based solution. Indeed, with a pricing-based solution, the outcomes are uncertain since the price elasticity of the car users is unknown (Fan and Jiang, 2013). Its higher effectiveness is beneficial for road authorities and may enhance public acceptability as well. Second, TPC do not require a financial flow from road users to the government, which may positively affect public support since it may not be perceived as 'yet another (road use) tax'. Lastly, the allocation of free credits provides the opportunity to address equity issues in a flexible way when they are used to provide subsidies to specific groups of citizens.

The notion that TPC can count on stronger public support is incited by empirical studies on the related concept of personal tradable carbon permits. This concept aims for a general reduction of carbon and includes travel but also domestic energy use. Studies generally find stronger support for proposed tradable carbon permits than for an equivalent carbon tax (Bristow et al., 2010; Harwatt et al., 2011; Knobelsdorff, 2008; Wallace et al., 2010). Support levels between 42% – 44% are reported in these studies although it can reach up to 80% (Bristow et al., 2010) depending on the exact scheme design. In particular, the way in which the permits are allocated is found to influence support. However, whether these relatively high acceptability levels also hold for permits applied to mobility management is unsure, since people in a tradable carbon scheme are less restricted in their behaviour because they can reduce their carbon in different ways. For example, they can choose to reduce their car use, but if they don't want to do that, they can also choose to reduce their flights, or isolate their homes, etc. and still reach a reduction in carbon. Whereas in a TPC scheme, people can only reach the goal (less trips in peak hours) by changing their car use during peak hours. The few studies that looked into the acceptability of credits for mobility management show diverse results. Kockelman and Kalmanje (2005) surveyed citizens of Austin (Texas) asking about the hypothetical introduction of a (non-tradable) credit-based congestion pricing (CBCP) scheme and found that 24.9% of the respondents would support the introduction. They conclude that this is a substantial number given the unfamiliarity with the concept. Dogterom et al. (2018a) found relatively high support for tradable driving credits (TDC) among car users in Beijing, but rather low support in the Netherlands. The acceptability levels were 67.0% and 21.6%, respectively. However, the way in which these schemes are explained to the respondents in these two studies fundamentally differ from TPC in a few aspects. It is unclear whether CBCP has a firm limit (*cap*) on the number of credits. Related to that, what is also not mentioned is whether the additional credits that people can buy have a fixed price or a price set by demand and supply. Explaining to the respondents that a scheme has a firm cap and a market mechanism might increase people's support since it may enhance the expected effectiveness, but may also negatively affect support

¹ Other studies also refer to the concept as marketable/transferable rights or permits.

since trading requires more effort and a firm cap might infringe on people's perception of freedom. The TDC scheme does not contain a time component since it focuses on the reduction of total kilometres driven whereas TPC aims to reduce congestion during peak hours. This time component may affect public support. According to Jaensirisak (2005), acceptability is higher when a charge focuses on peak periods only, whereas other studies found lower acceptability levels for a peak charge than for a tax without a time component (Francke and Kaniok, 2013; Gehlert et al., 2011). To the best of our knowledge, public support of personal credit schemes applied on mobility management has only been the topic of a few studies (see Table 1 for an overview) and none of them focused on scheme design aspects, whereas many of the scheme characteristics may be important for support.

The main aim of this study is therefore not only to quantify public support for the implementation of TPC, but also to explore the influence of some scheme characteristics (see Section 2.3). Furthermore, since previous road pricing acceptability studies showed that support levels can be explained not only by scheme characteristics, but also by certain socio-economic characteristics, and to a greater extent, by attitudes, such as fairness and expected effectiveness, the influence of these variables will be examined as well. To serve these aims, a stated choice experiment was conducted with 502 citizens from urban areas in the Netherlands participating.

This paper is structured as follows: Section 2 presents the conceptualization, by describing three categories of factors that may affect public support and by selecting attributes (scheme characteristics) for the stated choice experiment (see Section 3.2). Section 3 describes the methodology that includes the data collection, data preparation and method of analysis. Section 4 presents the results of the final estimated model and Section 5 presents the application of the model in order to gain insights into the support levels of different TPC schemes. Section 6 ends the paper by drawing conclusions, providing policy recommendations and discussing directions for further research.

2. Conceptualisation

To identify factors that may be relevant in explaining public support for TPC, we mainly relied on two sources. First, we reviewed the current literature. Since literature on public perceptions regarding tradable credits for mobility management is rather scarce, we expanded the review to include the acceptability of road pricing, which is abundant and discusses many factors that may also be relevant for TPC support. To supplement this review, we rely on the results of a focus group study we conducted, in which a total of 36 citizens discussed expected (dis)advantages, effectiveness and acceptability of TPC. Car users, as well as public transport and bicycle users, were shown a fictional city facing a congestion problem, and the participants were asked to discuss two instruments: a peak charge and TPC. The transcriptions of the discussions were content analysed. See Krabbenborg et al. (2020) for more details. From these two sources (literature and focus group meetings), we identified three categories of factors: socio-economic variables, attitudinal variables, and scheme design characteristics.

2.1. Socio-economic variables and mobility behaviour

Several socio-economic variables have been pointed out that correlate with the acceptability of road pricing measures. A few studies found a positive relationship between income and acceptability (Golob, 2001; Verhoef, Nijkamp and Rietveld, 1997a) whereas other studies did not find significant relations (Dogterom et al., 2018a; Jaensirisak, Wardman and May, 2005) and Harrington, Krupnick and Alberini (2001) found a negative relation. Gehlert et al. (2011) report a similar inconsistent picture regarding age, gender and level of education. Age has a small and negative effect on acceptability (Jaensirisak, Wardman and May, 2005), which also applies to being female (Börjesson et al., 2015). Regarding educational level, most studies report a positive relation to acceptability (Börjesson et al., 2015; Ubbels and Verhoef, 2006), while again Harrington, Krupnick and Alberini (2001) report a negative association. Furthermore, people who have a child in their household are more negative towards a congestion charge, which may be explained by higher car-dependency (Börjesson et al., 2015) and/or more time pressure. Residential location may also be a relevant factor: when Stockholm held a referendum about the introduction of congestion charging, people living in the areas around Stockholm were less supportive than people living within the city (Stockholms stad, 2007). This makes sense given that car trips passing the cordon payments stations are charged whereas car trips made within the affected area are not charged. Indeed, the intensity of car use has a negative relationship with acceptability (Börjesson et al., 2015; Eliasson and Jonsson, 2011; Gaunt, Rye and Allen, 2007) and people who do not use a car as their main mode of transportation are, in general, much more positive about road pricing than car users (Jaensirisak, Wardman and May, 2005; Zheng et al., 2014). Previous studies did not report a significant relationship between employment status and acceptability (Schuitema, Steg and Forward, 2010). It may be that people with a job are more negative about congestion pricing since they are less flexible in choosing departure time than people without a job. However, employed people do have a higher income, which has a positive relation with acceptability. Ubbels and Verhoef report that commuters who get financial compensation for their travel costs are more positive (2006). Hence, this study takes into account that both the socio-demographic mentioned, as well as mobility behaviour variables, are variables that could explain TPC support. We will refer to this group of factors as personal characteristics.

2.2. Attitudinal variables

People's attitudes generally seem to have more explanatory power than socio-economic variables in explaining support for pricing policy measures. These concern general beliefs and attitudes on the one hand, and attitudes towards the measure on the other hand. Acceptability is found to be higher when people have a higher problem awareness score (Eriksson, Garvill and Nordlund, 2006; Harrington, Krupnick and Alberini, 2001) or, more specifically, environmental concern (Eliasson and Jonsson, 2011). Perceived

Table 2
Overview of attributes and attribute levels used in the choice experiment.

Attribute	Levels
Eligible recipients of free credits	R1_All residents of the municipality R2_All residents of the municipality who own a car R3_All residents of the municipality + people who work there R4_All residents of the municipality + people who work there and own a car
Distribution principle	D1_Credits are equally distributed among all recipients D2_People who have travelled more km will receive more credits D3_People who work more hours per week receive more credits than people who work less hours per week D4_People with a lower income receive more credits than people with a higher income
Credit allocation interval	I1_Weekly I2_Monthly
Credit price fluctuation	F1_Every minute F2_Every day

behavioural control is also positively associated with acceptability (Sun, Feng and Lu, 2016). Regarding attitudes towards the measure in particular the perception of fairness (e.g. Di Ciommo, Monzón and Fernandez-Heredia, 2013; Eriksson, Garvill and Nordlund, 2006; Jakobsson, Fujii and Gärling, 2000; Sun, Feng and Lu, 2016) is often reported as a factor that is strongly related to support. Acceptability is also higher when people do not perceive the scheme as an infringement on their freedom (Jakobsson, Fujii and Gärling, 2000; Kim et al., 2013; Sun, Feng and Lu, 2016). According to Bamberg and Rolle (2003) these concepts of perceived infringement on freedom and perceived unfairness are strongly related. However, Schade and Schlag (2003) conclude that problem perception only contributes to acceptability to a negligible extent. Furthermore, acceptability is higher when people are positive about the expected personal outcome (Hamilton et al., 2014; Schade and Schlag, 2003), when they have trust in public agencies who need to conduct the policy (Hamilton et al., 2014), and when they believe the scheme is effective in reducing congestion (Eliasson and Jonsson, 2011; Rienstra, Rietveld and Verhoef, 1999; Schade and Schlag, 2003; Ubbels and Verhoef, 2006). The relationship between the expected effectiveness and acceptability is, however, under discussion since it can be hypothesised that respondents respond strategically by claiming that they perceive the instrument to be ineffective to justify their rejection (Rienstra, Rietveld and Verhoef, 1999). Schade and Schlag (2003), however, could not find evidence for this hypothesis. Our focus group meetings complement this list by adding a few more attitudinal factors. The results suggest that the expected fun of trading and belief in technical feasibility are positively related to TPC support, whereas the expected ‘hassle’ (in terms of expected time and effort), expected misuse and the perceived complexity of the scheme seem to negatively influence people’s standpoints towards TPC. Lastly, a few participants in the focus groups mentioned disliking TPC because it means that the travel costs are uncertain due to the fact that the credit price fluctuates. To explore the relationships between attitudes and support of TPC, all these attitudinal factors will be taken into account in this study.

2.3. Scheme design characteristics

With respect to scheme design, literature on road pricing acceptability shows that a range of characteristics influence public support. The charge level and the way in which revenues are used are found to be especially important (Jaensirisak, Wardman and May, 2005; Schade and Schlag, 2003; Schuitema and Steg, 2008; Ubbels and Verhoef, 2006). Also, the complexity of the scheme is found to play a role, as people strongly prefer simple tariffs (Bonsall et al., 2007). Regarding TPC, many more scheme characteristics can be determined that may influence support. These characteristics include the validity of the credits, the collection/verification service, the way in which credits are traded and trading rules (e.g. presence/absence of a maximum credit price), the scheme operator, the selection of recipients of credits, the ways that the credits are allocated, and so on. See Fan and Jiang (2013) for an overview of design characteristics of tradable credit schemes.

Since understanding the trading aspect of TPC already demands a significant amount of cognitive effort from the respondents, we decided to include only a limited number of varied design characteristics in the choice experiment to avoid overloading respondents with too much information. The literature review and insights from the focus group meetings were used to make a shortlist of design elements that are expected to influence people’s support of TPC the most. Then, in consultation with five experts from the fields of economy, transport policy, behavioural sciences and psychology, four fundamental choices regarding the TPC design were selected that are expected to influence people’s preferences most. These elements were translated into attributes and levels, which are described and discussed in the subsections below.

2.3.1. Eligible recipients of free credits

Several studies on tradable permits (Bristow et al., 2010; Grant-Muller and Xu, 2014), as well as the focus groups on TPC and the experts we consulted, conclude that the allocation of the credits is likely to be very important for the support levels. Indeed, the way in which credits are allocated and to whom, greatly determines the redistribution of welfare. Hence, credit allocation is included in the experiment in the first two attributes. The first attribute ‘eligible recipients’ concerns who will receive free credits. Eligible recipients can be the residents living in the municipality where TPC is introduced. Another option is to also allocate credits to people who work in that area. Furthermore, in the focus group meetings, some participants considered TPC an instrument to manage current car use and therefore suggested that credits should only be allocated to car users. Other participants argued that everyone has an equal right to use

Table 3
Socio-economic variables.

Variable	Categories
Gender	Male Female
Educational level	No educational qualification, primary school Preparatory secondary vocational education (basic), intermediate vocational education level 1 Preparatory secondary vocational education (theoretical), higher general secondary education & pre-university education (year 3) Intermediate vocational education level 2, 3 or 4 Higher general secondary education & pre-university education (year 5/6) Bachelor's degree Master's degree, PhD
Age	In years (18 years and older)
Place of residence	Lives in the municipality of Amsterdam / Utrecht Lives outside the municipality of Amsterdam / Utrecht
Work situation	Student / in training Retired Paid job Other (unemployed, voluntary work, etc.)
Children in the household	Yes No
Driving license	Yes No
Car is main mode of transport	Yes No
Travel costs	Yes (I have commuting costs that are not reimbursed, or are only partially reimbursed) No (I have no commuting costs, or my commuting costs are fully reimbursed)
Weekly number of trips during peak hours	In numbers per week (0 to 10)
Weekly number of trips during peak hours in slow traffic/congestion	In numbers per week (0 to 10)

the road and the credits should therefore be allocated to all people, thus regardless of whether or not they drive or own a car. In total, four levels were selected to vary who receives credits (see [Table 2](#)).

2.3.2. Distribution principle

The second attribute concerns the way in which the credits are allocated. The credits can be distributed to all recipients in a uniform way, but it is also possible to distribute them in such a way that certain groups in society are spared. Three non-uniform distributions were chosen: more credits for lower incomes, more credits for people who work more, and more credits for people who travel more.

2.3.3. Credit allocation interval

The focus group meetings suggest that expected 'hassle' (referring to time and effort) is an important factor in explaining people's support. Support is expected to increase when the scheme requires limited effort by the user. There may, however, be an inverse relationship between simplifying the scheme (in terms of hassle) on the one hand, and the efficiency of the scheme on the other hand ([Verhoef, Nijkamp and Rietveld, 1996](#)). The 'credit allocation interval' attribute is therefore interesting to study, as it concerns the frequency of the credit distributions among the recipients. Here it is assumed that credits remain valid for the entire time interval. Thus, if the interval is a week, the credits are valid only in that week. A shorter interval requires more hassle since people have to trade on a weekly basis, but can be more effective than a monthly interval since the regulator can adjust the cap more often. Two levels were selected for this attribute: a weekly and a monthly interval.

2.3.4. Credit price fluctuation

The final attribute is also about the balance between hassle and effectiveness. This attribute entails how often the credit price fluctuates. Although real-time dynamic pricing is better to balance supply and demand ([Verhoef, Nijkamp and Rietveld, 1996](#)), it may negatively affect the acceptability since it brings uncertainty about the cost, according to the focus group results. Two levels have been chosen: every minute and every day. [Table 2](#) provides an overview of all scheme characteristics that were varied in the stated choice experiment.

	Peak credit system 1	Peak credit system 2
How often are credits distributed?	Weekly	Monthly
Who receives credits?	Residents + employees Amsterdam	Residents + employees with car Amsterdam
How are credits distributed?	Equal distribution	People with a lower income receive more credits
How often does the credit price change?	Every minute	Every day

Which peak credit system do you prefer?

Peak credit system 1

Peak credit system 2

What would you vote for?

In favor of the introduction

Against the introduction of the tradable peak credit system I have chosen

Fig. 1. An example of a choice set for participants in the Amsterdam region (translated from Dutch).

3. Methodology

An online survey was designed consisting of four parts. In the first part, the respondents received an introduction which explained the concept of TPC². Basically, the respondents were presented with a TPC scheme that can be applied on all highways and provincial roads in the city during peak hours on weekdays. The peak hours are 07:00–09:15 and 16:00–18:15. The government decides how many credits are issued and they are distributed free of charge. Compared to the current situation, the number of cars using peak hours should decrease by 10%. Participants have a personal online account to manage their credits and they can also trade their credits here. The price of a credit is determined by supply and demand, but the maximum credit price is set at EUR 6. People cannot buy more credits than they can use themselves in a particular specified period of time, which is the credit allocation interval (see Section 2.2.3). The credits are redeemed automatically when people use the specified roads during the specified time slots. If people drive there with an empty credit account, they receive a notification to buy a credit. If they do not do this, the system will automatically charge them for a credit plus a small fee of EUR 1 extra. Next, the attributes and their levels were described. The complete text of the introduction can be found in Appendix A.

In the second part, the respondents were presented with six choice tasks, where they were asked to choose between the different TPC schemes explained in Section 3.1 of this paper. In the third part, the respondents were shown the attitudinal indicators on a 5-point Likert scale. The statements are based on the review of the literature that we did and the results of the focus group meetings, and these are explained in full in Section 3.4. The fourth and final part contained questions about the respondents' socio-demographic characteristics and travel behaviour. Table 3 shows these socio-economic variables and their categories.

² For the purpose of a different study, the fixed scheme design was presented to the respondents in four slightly different versions. The versions differed from each other in medium (two versions were shown in an animated video and two were presented in text) and in content (two version contained the basic information and two versions also included additional information about congestion problems). The versions were randomly assigned to the respondents. The influence of the different introductions was tested by including them in the model estimation and since the results were insignificant, these context variables will not be discussed in the remainder of this paper.

3.1. Experimental design

An orthogonal fractional factorial design was used to create the choice sets using Ngene software (ChoiceMetrics, 2018). In total, 12 choices sets were generated and each set had two unlabelled alternatives. Because the respondents of a pilot study found the alternatives rather complex, we blocked the design into two sets, with 6 choices each. Each respondent was randomly assigned to one block.

In each choice task, the respondents were first presented with two TPC schemes and were then asked to choose which one they preferred. To measure support for TPC as a policy instrument, they were next asked whether they would vote in favour or against the implementation of their preferred TPC scheme, should they be asked in a referendum. Fig. 1 shows an example of one of the choice sets and two questions (English translation of the original Dutch version). In the data analysis, these two questions were merged into a single variable. When people voted in favour of the preferred peak credit system, the preferred alternative was coded as ‘1’ or ‘2’, and when they voted against implementation, this was coded as ‘3’.

3.2. Model specification and estimation

To explore people’s preferences for TPC scheme designs, a discrete choice model, based on the utility maximization theory (McFadden, 1986), was estimated using the observed choices. This model assumes that the respondent tries to maximize their utility and thus chooses the alternative that offers the highest utility. The utility $U_{n,TPC}$ that a respondent n assigns to a TPC alternative is determined by observable factors (systematic utility) and the error term, $\epsilon_{n,TPC}$. For the observable factors, parameters, β , are estimated. In this paper, three categories of observed factors have been identified, as explained in section 2: scheme characteristics (attributes), personal characteristics and attitudinal variables. In Eq. (1), β_x is the vector that stands for the attributes X , β_k for the personal characteristics K , and β_l for attitudinal variables L . In this model, we will also study how some personal characteristics relate to preferences by including the interaction-effects of attributes with socio-economic variables. Furthermore, a constant, C_{TPC} , is added which captures the utility that people attach to the TPC system when all attributes have a zero value. This captures the base preference of TPC relative to the base alternative of ‘no implementation’, which captures all factors associated with TPC that are not varied in the experiment.

When the random error term can be assumed to be independently and identically distributed, the simple Multinomial Logit (MNL) model can be used to estimate the values for the coefficients. However, the MNL model is not able to capture the unobserved correlations that are expected between the two TPC alternatives. These can be captured by adding an error component to the utility function, representing the utility of the unobserved factors in the TPC alternatives, $\vartheta_{n,TPC}$ as shown in Eq. (1). Furthermore, the MNL model assumes that tastes regarding the attributes do not vary across individuals beyond those captured by the socio-demographic and attitudinal variables that are included. Taste heterogeneity can be examined by allowing β ’s to vary randomly within the population. Lastly, as each respondent made 6 choices, we assume that a person’s choices are correlated to some extent. To capture these effects, a panel Mixed Logit (ML) model with an error component structure is estimated. The utility function can be found in Eq. (1) and we refer the reader to Train (2003) for a more detailed description of the Mixed Logit model.

$$U_{n,TPC} = C_{TPC} + \beta_x X_n + \beta_k K_n + \beta_l L_n + \vartheta_{n,TPC} + \epsilon_{n,TPC} \tag{1}$$

where:

$$\vartheta_{n,TPC} \sim N(0, \sigma_{\vartheta,TPC})$$

$$\beta_{n,x} \sim N(\beta_x, \sigma_{\beta_x})$$

And the probability that citizen n supports TPC can be calculated using this formula:

$$P_{n,TPC} = \int_{\vartheta_n, \beta_n} \left(\prod_{i=1}^6 (P'_{n,TPC} | \vartheta_n, \beta_n) \times f(\vartheta_n, \beta_n) \right) \times d\vartheta_n d\beta_n \tag{2}$$

3.3. Sample

We argue that a first implementation of TPC would be most likely to take place in a large city, since congestion problems are worst in urban areas. We find that it is relevant to study not only the public acceptability of city inhabitants, but also the public acceptability of the inhabitants of municipalities adjacent to a city. For these reasons, people living in and near two of the biggest municipalities in the Netherlands were sampled: Amsterdam and Utrecht. Both groups received a survey in which TPC was suggested in their region. A company called CG Research was hired to collect responses using their online panel. Only respondents 18 years and older were invited to participate in this survey. As a reward, respondents received points, worth EUR 1.50, which they could exchange for a gift voucher from an online store.

In total, 889 people opened the survey, and of these, 513 people actually completed the survey. We checked these 513 responses for inconsistencies and unreliable answers. We tested that clicking through the survey without reading anything takes a minimum of 210 s for the survey with a text as introduction, and 360 s for the survey with a video. Hence, we assumed that those respondents who completed the survey faster than the minimum time required, did not provide valid responses. Eight respondents were removed from the database on this basis. Another three respondents were removed because of missing values on key variables. This led to a remaining

Table 4
The main socio-economic characteristics of the sample compared to the population.

Socio-economic variable	Category	Share sample [%]	Share population [%]
Gender ^a	Male	42.2	49.4
	Female	57.8	50.6
Age ^a	18–24	6.2	13.7
	25–44	31.3	45.2
	45–64	30.6	29.3
	65–79	30.1	11.6
	80+	1.8	3.3
Level of Education ^a	Low	12.7	16.2
	Medium	33.2	27.1
	High (University)	54.0	56.6
Employment ^a	Student/in training	5.4	11.1
	Retired	24.7	13.4
	Paid work (up to 20 h/week)	11.2	68.0
	Paid work (20–35 h/week)	17.7	
	Paid work (35 + hours/week)	25.3	
	Other (e.g. incapacitated, volunteering)	15.7	7.5
Gross Household Income (Euros/yr) ^b	<10,000	4.6	4.9
	10,000 – 20,000	10.6	25.9
	20,000 – 30,000	15.5	32.4
	30,000 – 40,000	15.9	21.2
	40,000 – 50,000	11.4	8.9
	50,000 – 100,000	18.6	5.9
	100,000 +	2.8	0.7
	unknown	20.7	

Education categories: Low: no academic certificate, primary school, preparatory secondary vocational education, intermediate vocational education level 1. Middle: higher general secondary education, pre-university education, intermediate vocational education level 2, 3 or 4. High: Bachelor's degree, Master's degree, PhD.

^a compared to the population of people living in Amsterdam and Utrecht municipality (CBS, 2019a, 2019b).

^b compared to the Dutch population (CBS, 2017).

Table 5
Rotated factor-loading matrix (factor loadings < 0.30 are not shown) and the Cronbach alpha test results.

Label	Indicator	Factor							Cronbach alpha
		1	2	3	4	5	6	7	
1: Expected effectiveness	I think TPC reduce congestion	0.932							0.918
	How effectively do you think TPC reduce congestion?	0.817							
	I think TPC will reduce the impact of car use on the environment	0.813							
2: Importance of certainty	I find it important to have certainty about my travel costs		0.790					0.654	
	I find it important to have certainty about my travel times		0.573						
3: Expected hassle	I think trading in peak credits requires a lot of effort			0.885				0.820	
	I think trading in peak credits requires a lot of time			0.705					
	I find TPC very complex			0.663					
4: Infringement	I think TPC harm people's privacy				0.753			0.78	
	I find TPC an infringement on people's (mobility) freedom				0.731				
5: Perceived fairness	How fair do you consider TPC for yourself?					0.740		0.823	
	How fair do you consider TPC for others?					0.606			
	I think TPC will give me financial benefits					0.550			
6: Trust	The trading in peak credits sounds like fun to me					0.524		0.783	
	I think a system with TPC is technically feasible						0.844		
	The government is capable of implementing and conducting a system with TPC						0.725		
7: Problem perception	Congestion is a big threat to the economy							0.680	
	Congestion is a big threat to the environment							0.652	
8: Personal problem perception	I personally suffer from congestion							Communality is too low	
9: Perceived behavioural control	It is easy to find alternatives for most car trips in peak hours (such as bicycle, public transport or other travel times)							Communality is too low	

Table 6
Correlation with attitudes.

	1	2	3	4	5	6	7	8	9
1	1	0.096**	-0.370**	-0.461**	0.788**	0.643**	0.371**	-0.483**	0.182**
2	0.096**	1	0.281**	0.189**	0.039	0.117**	0.430**	0.168**	0.160**
3	-0.370**	0.281**	1	0.508**	-0.229**	-0.343**	0.002	0.520**	0.103**
4	-0.461**	0.189**	0.508**	1	-0.441**	-0.376**	-0.127**	0.632**	-0.081**
5	0.788**	0.039	-0.229**	-0.441**	1	0.717**	0.361**	-0.449**	0.351**
6	0.643**	0.117**	-0.343**	-0.376**	0.717**	1	0.279**	-0.320**	0.230**
7	0.371**	0.430**	0.002	-0.127**	0.361**	0.279**	1	-0.210**	0.253**
8	-0.483**	0.168**	0.520**	0.632**	-0.449**	-0.320**	-0.210**	1	-0.121**
9	0.182**	0.160**	0.103**	-0.081**	0.351**	0.230**	0.253**	-0.121**	1

sample size of $N = 502$ respondents. This means that $6 * 502 = 3012$ choices were observed in the choice experiment. The median value of time spent on the survey was 812 s (13.5 min).

Although the literature review showed that socio-economic variables are not strong predictors of acceptability, the sample was meant to be representative for the population in these areas, as far as possible. Table 4 shows the comparison between the main-socio economic variables of the sample and the population. Since distributions on socio-economic variables for the population of people living near Amsterdam and Utrecht are not readily available, we used distributions of those variables for the municipalities of Amsterdam and Utrecht as proxies (see table 4). Females, retired people and people in the age category 65–79 years of age category seem to be somewhat overrepresented in the sample, and lower and higher educated people are slightly underrepresented. The survey was quite long so this may have resulted in less respondents with a higher value of time (people that have a job and or are higher educated). The underrepresentation of lower educated people may be caused by the somewhat complex topic. The representativeness of the sample regarding income could not be determined due to a large amount of missing values, though we can conclude that all income categories are fairly well represented. Regarding mobility habits, 44% of the sample use the car as their main mode of transport, 1% a motorcycle, 17% train/bus/metro, 29% (e)bicycle, 2% moped and 5% walk. Regarding residential location, 62% of the sample ($N = 310$) live within the borders of Amsterdam and Utrecht, and 38% live outside the borders. See appendix B for descriptive statistics regarding the attitudinal variables. Although the sample is somehow skewed in some respects, all the main socio-economic groups are well represented, and since socio-economic variables are not strong predictors of acceptability, we believe the sample is suitable to gain a first insight into the acceptability of TPC and how it relates to background variables, which is the purpose of our study.

3.4. Construction of attitudinal scales

In order to construct attitudinal scales, the 23 attitudinal indicators were exploratory factor analysed (see Appendix B for the complete list of 23 indicators). The extraction method of principal axis factoring was used in combination with the Direct Oblimin rotation technique. Indicators with a communality of <0.25 or with factor loadings of <0.50 were removed. A simple structure was formed with a 7-factor solution, as shown in Table 5. In total, 18 of the 23 indicators are part of the factor solution. In order to check for internal consistency of the factors, a Cronbach's Alpha test was conducted on the variables with high loadings on the same factor. The second and seventh factor have values of 0.654 and 0.682, which do not meet the widely accepted 0.7 criterion on the reliability scale. However, values between 0.6 and 0.7 are still considered acceptable in exploratory research (Taber, 2018). Hence, we decided to construct these attitude scales by taking the average of the scores of the high loading indicators. The attitudinal variables that were constructed were labeled as follows: expected effectiveness, importance of certainty, expected hassle, expected infringement, perceived fairness, trust, and problem perception.

Of the 5 statements which were excluded from the exploratory factor analysis, there are 2 statements that clearly represent attitudes that are different from the 7 scales that are of interest. Since both statements may be relevant to explain TPC acceptability, they were both included as potential predictors in the model estimation. These statements are labelled as personal problem perception and perceived behavioural control. Table 6 shows the correlations between the nine attitudes we distinguished. Unsurprisingly, expected effectiveness (scale 1), perceived fairness (scale 5) and trust (scale 6) correlate relatively highly.

3.5. Model estimation procedure

Since all attributes that were varied in the choice experiment were discrete variables, they needed to be coded. For this purpose, we applied effect coding instead of dummy coding. In effect coding, an attribute with two levels has an indicator variable that can have the values -1 and 1 . An attribute with four levels is coded with three indicator variables in which the values $1, 0, 0, -1$ are used for the first indicator variable, $0, 1, 0, -1$ for the second indicator variable and $0, 0, 1, -1$ for the third indicator variable. To give an example, the third level (D3) of the attribute credit distribution is coded as $[0, 0, 1]$ and is therefore equal to the third indicator variable in the model. The fourth level (D4) is coded as $[-1, -1, -1]$ and is equal to the negative sum of all three indicator variables. Hence, the sum of the utility contribution of the levels of each attribute always adds up to zero and therefore the average contribution of the levels of each attribute is also equal to zero. The consequence of this, and this is the main advantage of effect coding, is that the estimated constant can be interpreted as the average utility derived from all the TPC alternatives that are presented, compared to implementing none of

Table 7
Main statistics of the different models and the coefficients. The last column is the final model.

Model Categories of variables and sigma included	MNL			Panel ML error component	
	X	X +K	X+ K +L	X+ K +L	X+ K +L + sigmas
Final LL	-3110.028	-3070.562	-2664.768	-2235.322	-2188.167
LRS	437.534	78.932	811.604	858.892	94.31
Rho-square	0.063	0.078	0.193	0.324	0.339
	Coefficients (p-value)	Coefficients (p-value)	Coefficients (p-value)	Coefficients (p-value)	Coefficients (p-value)
Constant_TPC	-0.693 (0.00)	-0.487(0.00)	-4.09(0.00)	-2.92(0.00)	-3.4 (0.00)
F1_fluctuation_minute	-0.105(0.01)	-0.104(0.01)	-0.110(0.01)	-0.109(0.02)	-0.192 (0.00)
F2_fluctuation_daily	0.105	0.104	0.110	0.109	0.192
I1_interval_weekly	-0.0797 (0.01)	-0.080(0.01)	-0.0867(0.01)	-0.106(0.00)	-0.147 (0.00)
I2_interval_monthly	0.0797	0.080	0.08367	0.106	0.147
D1_equal distribution	0.276(0.00)	0.279(0.00)	0.314(0.00)	0.386(0.00)	0.599 (0.00)
D2_more km traveled, more credits	0.0120(0.89)	0.157(0.85)	-0.00698 (0.94)	-0.05(0.617)	-0.101(0.414)
D3_more hrs working, more credits	-0.159(0.01)	-0.164(0.01)	-0.166(0.01)	-0.169(0.03)	-0.234 (0.02)
D4_lower income, more credits	-0.129	-0.272	-0.141	-0.167	- 0.264
R1_residents municipality	-0.245(0.00)	-0.247(0.00)	-0.281(0.00)	-0.186(0.00)	-0.287 (0.00)
R2_residents municipality who own car	-0.0209 (0.81)	-0.0223(0.80)	-0.00234 (0.80)	-0.0312 (0.77)	0.0659 (0.624)
R3_residents municipality + people who work there	-0.0455 (0.46)	-0.0439(0.47)	-0.0302(0.65)	0.0192(0.81)	0.0624 (0.494)
R4_residents municipality + people who work there that own a car	0.3114	0.3132	0.3135	0.198	0.1587
Level of education		-0.0567(0.03)	-0.169(0.00)	-0.323(0.01)	-0.346 (0.01)
work situation_other		0.0794(0.38)	0.162 (0.11)	0.328(0.47)	0.428 (0.35)
work situation_retired		0.336(0.00)	0.429(0.00)	0.589(0.07)	0.503 (0.14)
work situation_student		-0.416(0.00)	-0.591(0.00)	-1.17(0.02)	-1.13 (0.03)
Work situation_paid job		0.0006	0.000	0.253	0.199
Gender_male		-0.000103 (0.00)			
Weekly number of car trips during peak hours in congestion		0.104(0.00)			
Weekly number of car trips during peak hours		-0.0416(0.06)			
Income		-0.000385 (0.00)			
Having travel expenses		0.0902(0.03)			
Residence in municipality				-1.46(0.00)	-1.7 (0.00)
Interaction_residence in municipality_R1				-0.186(0.00)	-0.287 (0.00)
Attitude_perceived fairness			0.612(0.00)	1.12(0.00)	1.21 (0.00)
Attitude_expected effectiveness			0.517(0.00)	1.1(0.00)	1.17 (0.00)
Attitude_trust			0.168(0.00)	0.394(0.05)	0.496 (0.02)
Attitude_importance certainty			0.231(0.00)	0.391(0.07)	0.509 (0.03)
Attitude_infringement on freedom			-0.136(0.00)	-0.293(0.09)	-0.342 (0.09)
Sigma_C_TPC				-3.06(0)	3.33 (0)
Sigma_D1_equal distribution					0.681 (0.00)
Sigma_D2_more km traveled, more credits					0.662 (0.00)
Sigma_D3_more hrs working, more credits					0.74 (0.00)
Sigma_R1_residents municipality					0.648 (0.00)
Sigma_R2_residents municipality who own a car					0.31 (0.04)

these policy measures (the base alternative). The utility contribution of an attribute level then expresses the difference compared to the average utility. The socio-economic variables were also effect coded, except for level of education and age. See [Bech and Gyrd-Hansen \(2005\)](#) for more information on effect coding in choice experiments. Biogeme ([Bierlaire, 2018](#)) was used to estimate the discrete choice models.

Because we are interested in how groups of variables contribute to the explanation, we estimated and compared a series of models. First a simple MNL model was estimated containing only the attributes (X), which is a significant improvement over the null-model (see [Table 7](#) for fit measures). Then, personal characteristics (K) were added to the model, which led to a small yet significant improvement of the model fit. Thirdly, attitudinal variables (L) were added, which led to a strong improvement of the model fit. As explained in Section 3.4, the attitude variables were first determined by the use of an exploratory factor analysis and then incorporated in the utility function of the discrete choice model. In this sequential procedure it is assumed that the factor scores that represent the attitudes are free of measurement error. A simultaneous estimation, as done in hybrid choice models, can take these measurement errors into account. This more advanced procedure is usually preferred when one wants to study the influence of one (up to two or three) latent variables in depth, as more variables lead to complex models and may give estimation problems. Since many more attitudes were identified in this study on TPC support, we explored the influence of all these attitudes instead of studying a few in-depth.

Table 8
Results of the final panel ML model with error component structure.

Name	Value	Rob. Std err	Rob. t-test	Rob. p-value
Constant_TPC	-3.4	0.714	-4.76	0.00**
F1_fluctuation_minute	-0.192	0.0602	-3.19	0.00**
F2_fluctuation_daily	0.192			
I1_interval_weekly	-0.147	0.0435	-3.38	0.00**
I2_interval_monthly	0.147			
D1_equal distribution	0.599	0.108	5.56	0.00**
D2_more km traveled, more credits	-0.101	0.124	-0.816	0.414
D3_more hrs working, more credits	-0.234	0.102	-2.3	0.02**
D4_lower income, more credits	-0.264			
R1_residents municipality	-0.287	0.0601	-4.78	0.00**
R2_residents municipality who own car	0.0659	0.134	0.491	0.624
R3_residents municipality + people who work there	0.0624	0.0913	0.684	0.494
R4_residents municipality + people who work there that own a car	0.1587			
Level of education	-0.346	0.131	-2.64	0.01**
work situation_other	0.428	0.454	0.943	0.35
work situation_retired	0.503	0.339	1.48	0.14
work situation_student	-1.13	0.527	-2.14	0.03**
Work situation_paid job	0.199			
Residence in municipality	-1.7	0.357	-4.76	0.00**
Interaction_residence in municipality_R1	-0.287	0.0601	-4.78	0.00**
Attitude_perceived fairness	1.21	0.264	4.58	0.00**
Attitude_expected effectiveness	1.17	0.227	5.15	0.00**
Attitude_trust	0.496	0.218	2.28	0.02**
Attitude_importance certainty	0.509	0.228	2.23	0.03**
Attitude_infringement on freedom	-0.342	0.204	-1.67	0.09*
Sigma_C_TPC	3.33	0.245	13.6	0**
Sigma_D1_equal distribution	0.681	0.125	5.43	0.00**
Sigma_D2_more km traveled, more credits	0.662	0.116	5.69	0.00**
Sigma_D3_more hrs working, more credits	0.74	0.12	6.18	0.00**
Sigma_R1_residents municipality	0.648	0.125	5.18	0.00**
Sigma_R2_residents municipality who own a car	0.31	0.148	2.09	0.04**

**significant at 5% level.

*significant at 10% level.

Hence the sequential estimation procedure is more suited for the purpose of this study.

Then, the MNL model was extended to a panel ML model with an error component structure. That is, a nesting structure is added to the utility functions to capture the correlation between the two TPC alternatives, which is caused by attributes associated with TPC that are not varied in the experiment. This correlation is captured by an additional error component that is assumed to be normally distributed. The model is estimated, taking into account the panel effect, by acknowledging that the six choices made by the same respondent correlate, which results in correct t-values. This led to a significant and major improvement of the model fit. Lastly, the parameters of the attributes were estimated as random parameters with a normal distribution to study taste heterogeneity. Whereas the estimated parameters (Betas) represent the mean value of the population, the Sigmas represent the standard deviations. Thus, a Beta with a relatively large Sigma indicates a strong taste variation. The Sigmas related to the attributes regarding credit distributions turned out to be statistically significant. Including these Sigmas in the model led to a small yet significant improvement of the model fit.

Insignificant socio-economic and attitudinal variables were removed in the estimation procedure. These include variables related to gender, age, license possession, children in the household, car as main mode of transport, weekly number of car trips during peak hours, weekly number of car trips in congestion, whether people have travel costs for commuting trips, attitude to 'hassle', attitude to 'problem perception', attitude to 'personal problem perception', and attitude to 'perceived behavioural control'. Also several interaction-effects were tested and removed due to insignificant results. These include 'age and credit price fluctuation', 'income and distribution of credits', 'work situation and distribution of credits', 'having children and distribution of credits', 'educational level and allocation interval', 'frequency of car use and credit distribution', 'frequency of car use in congestion and credit distribution', 'car as main mode and recipients', 'car as main mode and credit distribution'.

The final model contains 26 parameters and was estimated using 2000 draws to get stable estimates. These were drawn from a Monto-Carlo simulation with a normal distribution. The following section will describe the results of this final model.

4. Results

The results of the final choice model are presented in Table 8. Keeping in line with the estimation procedure, we first discuss the attributes, followed by the personal characteristics (socio-demographic variables and mobility behaviour) and then the attitudes.

The constant is negative (-3.4), but it is hard to interpret the constant since not all of the variables included were effect coded. Nevertheless, since the first model, which only had the attributes (X), also had a negative constant, it can be interpreted that on average people prefer to maintain the current situation rather than implementing TPC. However, the sigma of the constant (3.33) is relatively

large, which shows that there is a high level of heterogeneity in unobserved preference for TPC alternatives compared to the status quo. In other words, preferences vary considerably. Regarding the attribute levels, support is stronger when the credit price fluctuates on a daily basis instead of every minute, when credits are distributed on a monthly basis instead of weekly, and when the credits are distributed ‘equally’ among ‘residents of the municipality plus the people who work there and own a car’. The values of the fluctuation and interval attributes imply that people generally prefer schemes that require less ‘trading hassle’. An additional explanation is that a daily price fluctuation gives less uncertainty about travel costs. Regarding credit distributions, people prefer an ‘equal distribution’ of credits, whereas the distribution in which lower incomes receive extra credits is least preferred. Nevertheless, the Sigmas are significant and relatively large. This means that tastes regarding the distributional principles are very heterogeneous. Thus, apparently, people on average prefer a scheme in which all people who (can) actually use the road receive credits. Hence, there is less support for giving credits to people who do not own a car. However, the Sigma related to ‘eligible recipients’ is large and significant, indicating that preferences regarding this attribute vary considerably as well. Thus, the way in which the credits are distributed, and to whom, is quite important, but consensus on this is a far cry.

Regarding personal characteristics and the interaction-effects between personal characteristics and attributes, only a few variables turned out to be statistically significant. Educational level, work situation and place of residence are significant. Higher educated people, students and people living within the borders of Amsterdam and Utrecht have a stronger dislike for TPC. Most earlier studies on the relation between conventional road pricing acceptability and educational level found a positive relation, as explained in Section 2.1. Dogterom et al. (2018a) however, also found a negative relationship between the acceptability of tradable driving credits and educational level, although it was not statistically significant. This is also interesting because an experiment on trading behaviour with parking permits (Brands et al., 2020) showed that higher educated people are better traders than lower educated people. Thus, this suggests that better trading skills do not necessarily lead to stronger support. Furthermore, people who live in the municipalities of Utrecht and Amsterdam have a larger dislike for TPC than people who live in the surrounding areas. This may seem surprising since in all TPC schemes, residents of Amsterdam and Utrecht receive credits whereas people living in the surrounding areas would only receive credits in two of the credit distributions (R3 and R4). A possible explanation is that people living in the municipality will always be confronted by TPC, whereas people living in the surrounding areas may have the option to avoid the area by traveling to other cities. Furthermore, it is remarkable that the inhabitants of Amsterdam/Utrecht are slightly more negative than average about the schemes in which only credits are given to them, instead of also giving credits to people from outside who work in the cities, for example, which seems to run counter to their self-interest.

Whereas the socio-economic variables and mobility behaviour explain relatively little about the support levels, the attitudinal variables explain more, according to the model fit improvement. Five attitudinal variables were found to significantly influence utility. Support is higher among people who perceive TPC as *fair* and *effective*, who have *trust* in the government and technical feasibility, who find *certainty* important, and do not consider TPC as an *infringement on their freedom* (only significant at a 10% level). The *perceived fairness* and *expected effectiveness* have the most influence on support and the signs of the coefficients are as expected. Less obvious is the positive value for the attitudinal variable *certainty*. This value indicates that people who consider it important to have certainty about travel costs and travel time show higher support for TPC. On the one hand, this makes sense because the introduction of TPC can make travel times less uncertain, but on the other hand, the travel costs become more uncertain. Thus, these people find certainty about travel times more important than certainty about travel costs, and/or they underestimate the increased uncertainty about travel costs within a TPC system. Within the set of attitudinal variables, we can conclude that ‘expected effectiveness’ and ‘perceived fairness’ have a stronger relation with support than the other three attitudinal variables.

5. Predicted support levels

Based on the Mixed Logit model, we conducted simulations to predict the support levels of different TPC schemes using our sample. As a reference scenario, we calculated support for the TPC scheme with the highest average utility first. In that scheme, *all residents of the municipality + people who work there and own a car* receive credits, which are *equally distributed* on a *monthly basis* and the credit price fluctuates *daily*. We first calculated the probability that an individual would choose that TPC scheme. We used 100 draws for each random parameter. The mean support for that TPC scheme is 52.4%, indicating that a small majority of this sample supports this scheme.

At the other end of the scale, the least preferred TPC scheme has an average support level of 32.3% and consists of a scheme in which only *residents of the municipality* receive credits whereas *people with a lower income receive more credits than people with a higher income*. Furthermore, the credits are distributed *weekly* and the credit price fluctuates *every minute*.

Table 9 illustrates the impact of changing one attribute level when all other levels remain equal to the most supported scheme. Thus if instead of *equal distribution*, more credits are given to people who travelled more, this leads to a drop in support of 6.9%. The table shows that actually any change in scheme design will cause a drop in support level below 50% and thus to a minority for support. Nevertheless, operators may consider to make the credit interval smaller and the fluctuation of the credit price higher, if that makes the scheme more efficient. These two adaptations lead to a small drop in support, leading to a support level of 47%.

Table 9

The changes in support levels for TPC design caused by different attribute levels. The scheme with the highest support level is taken as the point of reference.

Change in design variable			Average absolute change in support level
Design variable	Reference level	Other levels	
Recipients of credits	All residents of the municipality + people who work there and own a car	All residents of the municipality	-7.96%
		All residents in the municipality who own a car	-3.01%
Distribution principle	Credits are equally distributed among all recipients	All residents of the municipality + people who work there	-3.04%
		People with a lower income receive more credits than people with a higher income	-6.9%
		People who have travelled more km will receive more credits	-5.4%
Credit price fluctuation	Every day	People who work more hours per week receive more credits than people who work less hours per week D3	-6.73%
		Every minute	-2.98%
Credit allocation interval	Monthly	Weekly	-2.30%

6. Conclusion and discussion

This aim of this study was to explore public support for the novel concept of Tradable Peak Credits (TPC) as a policy instrument to reduce congestion. To that end, a discrete choice experiment was conducted, in which TPC schemes were varied in terms of who receive the credits, how these credits are distributed, how often they are distributed and how often the price fluctuates. In each choice set of the experiment, respondents first selected the TPC scheme they preferred and then indicated whether they would vote in favour or against this scheme in a referendum. A panel mixed logit model was estimated to examine the impact that the scheme characteristics, personal characteristics and attitudes had on support for the TPC scheme.

The results suggest that on average people prefer the status quo to implementing TPC. Overall, support increases if the credits are distributed monthly, the credit price fluctuates daily, and the credits are distributed equally, preferably among residents in the municipality + people who work there and own a car. This indicates that on average people prefer schemes that require less trading effort and in which credits are distributed equally, but preferably only to people who actually use the road. The tastes regarding the allocation of credits are however very heterogeneous. Depending on the scheme design, support levels range from 32.3% up to 52.4%. Thus, these results indicate that a small majority of people in this sample is in favour of the implementation of the most attractive TPC scheme. The support levels found in this study are higher than in the study on credit-based congestion pricing (CBCP) which found a support level of 24.9% (Kockelman and Kalmanje, 2005), and a tradable driving credit (TDC) scheme in the Netherlands that found a support level of 21.6% among car owners (Dogterom et al., 2018a). The support levels found for TPC are also slightly stronger than support for a congestion charge. A recent opinion survey (I&O research, 2019) reports that 32% of Dutch citizens support a congestion charge. However, concluding that people like the TPC scheme design more than a congestion charge, or TDC design, is probably too simplistic. When comparing these results, the sample and the way of questioning have to be kept in mind. For example, it is plausible that support for road pricing instruments is stronger in our sample of people from urban areas than the average of the Dutch population, since congestion problems are worse in and around cities. Furthermore, the TDC study, for example, found that 35% of the respondents had a neutral opinion, and in the congestion charge opinion study, this was 28%, whereas in our study, respondents were presented with a referendum-based choice in which they either voted against or in favour of the scheme. When comparing our results with support for CBCP, where the design is the most like the design of TPC, contextual factors have to be kept in mind. CBCP was suggested in Austin (Texas), where the hours lost in congestion are almost double to those in Utrecht and Amsterdam (Inrix, 2019), but still the reported support in Austin was lower than in this study. Other cultural and contextual factors may play a role here as well. For example, the Dutch may be more positive about road pricing instruments because they have, on average, better public transport alternatives and bicycle infrastructure. Another possible factor is that the Dutch are quite familiar with the concept of road pricing due to the longstanding national debate about it, and familiarity with road pricing is strongly related to support for CBCP, according to Kockelman and Kalmanje (2005).

Furthermore, the difference of 20 percent between the least (32.3%) and most supported (52.4%) scheme design, is less than in the earlier study on tradable carbon permits which found that support levels increased from 20% to 80% (Bristow et al., 2010). But this difference is still quite substantial, especially given that it can make the difference between a policy being 'rejected' or 'supported' by a majority of the people. Nevertheless, the strong improvement in model fit indicated that people's attitudes are very important in explaining their support. In other words, many people reject/accept TPC regardless of the scheme design. Remarkably, support is lower among people who live within the city boundaries, which contradicts the findings in Stockholm (Stockholms stad, 2007). The important role of attitudinal variables, including expected effectiveness, infringement on freedom and especially perceived fairness, is in line with earlier road pricing studies (Sun, Feng and Lu, 2016). However, the variables of problem awareness and perceived behavioural control were not significantly related to support, which contradicts with the theory of planned behaviour (Ajzen, 1991) and norm activation theory (Schwartz, 1977).

A few recommendations for policymakers can be made, based on the results. As explained above, the results indicate which scheme

design is most preferred. The preferences for the different credit allocations were, however, very heterogeneous and should be further explored. The results also emphasize that people prefer a scheme that requires the users to have less trading ‘hassle’. This is in line with what has already written about in road pricing literature, which found that people have a strong preference for a simple tariff structure (Bonsall et al., 2007), even though people do respond in a rational way to complex tariffs (Bonsall et al., 2007) and tradable parking credits (Brands et al., 2020) which indicates that they understand it. Thus from the perspective of optimizing support, a simpler scheme is advisable. From a broader perspective, however, it is important to study the balance between the complexity (or ‘hassle’) and the efficiency of the instrument. Generally, road pricing schemes become more efficient when the tariffs are more differentiated, which leads to a more complex, ‘hassleful’ scheme, which is less acceptable. If simplifying a TPC scheme leads to undermining its efficient properties, the motivation to implement the scheme no longer hold.

The results have to be interpreted with some caution since this is a first quantitative study regarding public support of this specific TPC, which has some limitations. TPC was presented to the respondents without mentioning system and administration costs. Due to the trading platform, it is likely that a TPC system will be more expensive for the operator (the government, in this case) than a congestion charge. It would be interesting to further study public support, using a representative sample, from a citizen’s perspective by confronting respondents with the societal costs (e.g. system costs) and benefits (e.g. reduction of congestion) of both instruments. Furthermore, only the influences of a limited set of variables are explored in this paper, whereas some more variables may be of relevance in explaining support. According to the theory of planned behaviour (Ajzen, 1991), social norms and perceived social pressure are relevant in explaining behaviour. When one feels social pressure to reduce car use, the acceptability of TPC may be higher. Also, in line with the norm-activation theory (Schwartz, 1977), acceptability may be higher when people feel morally obliged to change their (car use) behavior because they realize that their own car trips are part of the congestion problem. Sun, Feng and Lu (2016) already found empirical evidence for these relationships in the acceptability of road pricing. Moreover, this paper studied the support levels based on people’s first impression of this novel instrument, which they had never heard of before. TPC is new to people and some people might be reluctant to support an instrument they have never heard reliable experts speak about. In contrast, congestion pricing and kilometre charging schemes have increasingly received positive media attention in the Netherlands. It is unknown whether and how attitudes and acceptability change when people get more acquainted with the concept. Revealed preference studies that examine the support of people who have actually been using tradable credits in field studies would be very helpful in this respect. Finally, this study, quantifying the support for tradable credits for congestion management, suggests that the best TPC design may be supported by a small majority, at least in this sample, but still many aspects of TPC design have to be further explored to gain insights into the feasibility of TPC as a tool to manage congestion. Indeed, public support is an important requisite for the implementation of an innovation, but it is not sufficient, since the instrument should also be technically feasible, politically accepted, and the societal benefits need to exceed the costs (Feitelson and Salomon, 2004). The first lab experiments showed that people respond to the scheme in a logical way (Brands et al., 2020; Dogterom, Ettema and Dijst, 2018) but real world experiments are needed to better understand behavioural effects, to fine tune the design and to measure the acceptability better.

CRediT authorship contribution statement

Lizet Krabbenborg: Conceptualization, Methodology, Formal analysis, Writing - original draft. **Chris Langevelde-van Bergen:** Methodology, Investigation, Formal analysis. **Eric Molin:** Supervision, Writing - review & editing, Funding acquisition.

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Appendix A

In total, we used four introductions that were randomly assigned to the respondents. Half of the respondents received standard information about TPC, and the other half of the respondents received this standard information + information on the consequences of congestion and the effects of the instrument. Thereby, we also varied the form of the introduction. Half of the respondents received the information in text, the other half in a (animated) video. The author will share these videos on request. Table 10 details the four types of introductions.

The sentences about ‘info on problem and implications’ are in *italics* and were only presented to half of the respondents. Respondents who live in or near Utrecht, received the same text/video, but with ‘Amsterdam’ replaced by ‘Utrecht’.

Introduction text

There is often congestion in the Netherlands on weekdays. *The congestion levels are expected to further increase in the coming years if no measures are taken. Congestion costs car users a lot of time and gives them uncertainty about their travel times. Furthermore, congestion is bad for the economy, since it costs money when trucks or employees are waiting on motorways or when they have to take a detour. If congestion*

increases, the financial damage will also further increase.

A new plan has been thought of to deal with congestion: tradable peak credits (please note: this is something different to a peak charge or road pricing). The basic idea is that driving a car during peak hours (Monday to Friday, 07:00–09:15 and 16:00–18:15) costs a peak credit on all highways and provincial roads in the municipality of Amsterdam. If you drive on multiple roads during 1 peak period, this costs 1 credit. Credits are not needed outside of the municipality of Amsterdam and outside peak hours.

The number of available credits depends on the capacity of the area. Thus, an area that can handle a maximum of 9000 cars per peak period has 9000 credits. Compared to the current situation, the number of cars using peak hours should decrease by 10% to solve most congestion. The credits are distributed free of charge and people can use these credits to drive in peak hours. The government administers the system.

If people have more credits than they need, they can sell them to people who want more credits using an online trading platform. Buying and selling goes via an app or via computer. You don't need to search for a buyer/seller yourself: you buy and sell the credit to the platform for the credit price at that moment. The trading platform does not make profits. The government also does not earn money, since car users trade the credits with one another.

The price of the credits on the platform is determined by supply and demand. The price increases if the demand is high. The price decreases if the supply is high. The price of a credit is expected to lie between EUR 2 and EUR 4. The maximum price of a credit is EUR 6. You cannot buy more credits from the platform than you can use yourself (so in a week you can have a maximum of 10 credits in your possession, since you can drive in peak hours twice a day). This prevents people from hoarding credits with the aim of reselling credits and making a profit in that way.

When people register their car, the credits will be automatically redeemed from their 'credit budget' when they use the road(s) during peak hours. When someone enters the road and they don't have any credits, the system will send them a notification in the evening that they should buy a credit retrospectively. If they do not do this, the system will automatically buy a credit for them and charge them for it at the credit price at that moment, plus a transaction cost of EUR 1. People who have not registered their car (e.g. visitors) can buy credits for single-use for a number of days (online or at a gas station).

An example: a car user who previously drove in peak hours 8 times a week, receives 7 credits. If he keeps on driving in peak hours 8 times a week, he has to buy 1 credit. If he drives 7 times a week in peak hours, he does not have to sell nor buy credits. If he drives less than 7 times a week in peak hours, he can sell credits.

Researchers expect that tradable peak credits will strongly reduce congestion, since allocation of the credits gives control over the number of cars in peak hours. The introduction of tradable peak credits is expected to reduce the travel time losses due to congestion by 25% or more. Thus, this means that car users spend less time in congestion and hence they have less travel time loss and more certainty about their arrival time.

Table 10
The types of introductions.

Video standard	Text standard
Video standard + info on problem and implications	Text standard + info on problem and implications

Appendix B

See [Table 11](#).

Table 11
The set of 23 statements plus descriptive statistics.

Statement	How often an answer is given in percentages					Mean	Std. Dev.
	1	2	3	4	5		
I think TPC reduce congestion	23	18	26	23	10	2.79	1.29
How effectively do you think TPC reduce congestion? ^b	22	17	36	22	3	2.66	1.13
I think TPC will reduce the impact of car use on the environment	25	15	29	23	8	2.73	1.28
I find it important to have certainty about my travel costs	4	6	28	30	32	3.80	1.07
I find it important to have certainty about my travel times	4	4	24	38	30	3.86	1.03
I think trading in peak credits requires a lot of effort	7	16	28	29	20	3.40	1.17
I think trading in peak credits requires a lot of time	5	18	30	27	20	3.38	1.14
I find TPC very complex	13	20	31	22	15	3.05	1.22
I think TPC harm people's privacy	13	21	27	20	19	3.11	1.30
I find TPC an infringement on people's (mobility) freedom	10	15	25	24	27	3.43	1.30

(continued on next page)

Table 11 (continued)

Statement	How often an answer is given in percentages					Mean	Std. Dev.
	1	2	3	4	5		
How fair do you consider TPC for yourself? ^c	13	15	49	19	4	2.87	1.00
How fair do you consider TPC for others? ^c	12	22	42	20	4	2.81	1.01
I think TPC will give me financial benefits	31	18	30	14	6	2.46	1.23
The trading in peak credits sounds like fun to me	37	15	24	15	8	2.41	1.33
I think a system with TPC is technically feasible	13	15	32	27	13	3.13	1.20
The government is capable of implementing and conducting a system with TPC	25	15	33	19	8	2.70	1.25
Congestion is a big threat to the economy	3	7	26	35	29	3.81	1.03
Congestion is a big threat to the environment	3	3	17	34	42	4.09	1.00
I personally suffer from congestion	29	28	24	11	7	2.38	1.21
It is easy to find alternatives for most car trips in peak hours (such as bicycle, public transport or other travel times)	13	17	27	21	22	3.22	1.32
I think people will misuse a TPC system	3	8	24	31	34	3.84	1.08
I find TPC understandable	13	14	26	31	16	3.23	1.25
I think I will be worse off when TPC are implemented	19	16	29	16	19	3.00	1.36

The statements were answered on a Likert scale ranging from 1: totally disagree to 5: totally agree. Except for:

b: 1: not effective at all 5: very effective.

c: 1: very unfair 5: very fair.

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