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## What is the potential of hybrid cordon pricing policy for reducing and shifting car usage in cities?

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### Abstract

As cities need to urgently transition out of unsustainable mobility systems, following the Avoid-Shift-Improve framework, changes in travel behavior have a top priority. Although behavior change in is a complex phenomenon, previous research informs us about the importance of urban road-usage policy measures. One such policy measure is often referred to as congestion pricing (CP). Some cities have successfully implemented CP, showing its effectiveness potential in behavior change, but wide-spread implementation lags due to challenges in societal, organizational, and political acceptance and implementability. Emerging literature on mobility credits (MC), mostly based on experiments, has brought forward the questions of acceptance, showing different possibilities for credit allocation, accumulation and exchange. In addition to behavior change, cities in transition economies might also consider monetary policies as potential solutions to financing issues. This research aims to analyze benefits and challenges of implementing a hybrid scheme that is a combination of CP and MC, developed with an expectation for policy coherence and complementarity. To determine the effects of the proposed hybrid scheme, a comparative analysis of user attitudes on congestion charging was conducted. The research was conducted using an online questionnaire, and the target group consisted of the residents of Belgrade (Serbia). Since these strategies are not implemented in Belgrade, the stated choice approach was used. The survey contained questions about the socio-demographic characteristics of the users, trip characteristics, users' acceptability of CP and the hybrid scheme, as well as the questions on transport mode usage for commuting trips and for trips with other purposes. Based on statistical and policy analysis, it was determined that the hybrid scheme represents a suitable compromise solution which would reduce passenger car trips in the city center and while increase public acceptance for such normative policies.

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*Keywords:* urban mobility; modal shift; mobility credits; road pricing; policy acceptance;

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## 1. Introduction

The increasing motorization rate and share of private car trips in the modal distribution has numerous negative consequences for people and environment in cities (Mladenović et al., 2020; Mladenović et al., 2021). The modern sustainable mobility paradigm (Banister, 2008) suggests that modal shift policies are among the top priority actions for transitioning out of car-dependent urban mobility systems, as part of a larger Avoid-Shift-Improve policy set (Nakamura & Hayashi, 2013). Although mobility behavior change in is a complex phenomenon, policies for modal shift away from motorized and private car transport are generally divided into two main groups - push and pull measures. Push measures are intended to discourage private motorized transport, while pull measures are aimed to promote use of sustainable transport modes. One of the most important set of push measures refers to access control in the central city zone (CZ) for passenger car traffic. One of the basic concepts of access control is congestion pricing (CP), where passenger car users pay a monetary fee for entering CZ (Giuliano, 1992). Various versions of CP have been successfully implemented in several cities such as London, Stockholm, Milan, Singapore, and Gothenburg. However, in many cities, such as, Manchester, Copenhagen, Helsinki and Edinburgh, the implementation of CP has not been successful. Despite the fact that literature confirms that CP is a very effective policy (Milenković & Kocić, 2019), the main problem of CP implementability relates to public and political acceptance, and underlying social equity aspects (Albalade & Bel, 2009; Banister, 2003; Milenković et al., 2019; Li & Robuste, 2021). For example, extreme cases of insufficient public acceptance could result in boycott and demonstrations, as in Lyon, France (Raux & Souche, 2004).

In response to the equity challenge of CP, mobility credits (MC) policy is designed so that users are allocated with a limited number of mobility credits for a certain period (Gulipalli et al., 2008; Li & Robuste, 2021). Thus, when driving within a specific area, drivers will spend the allocated credits instead of a direct monetary fee. The expectation from MC policy is that it would limit the total use of passenger cars in the CZ without imposing additional financial costs to road users (Glavić et al., 2020). In contrast to CP, and despite the substantial amount of conceptual, qualitative and quantitative research, MC schemes are not implemented. The main challenge with implementability of MC policy relates to more complicated management and operation systems than traditional CP (Li & Robuste, 2021). Besides these global challenges, some particular contexts, such as transition economies, might also have a need to use monetary policies for funding basic infrastructure construction (Glavić et al., 2017; Politis et al., 2020). As it stands, both of these policy alternatives have a set of advantages and disadvantages, some overlapping and some complementary, as can be seen from Table 1.

Table 1. Comparative analysis of CP and MC scheme

Characteristics	CP	MC
VOT Savings	✓	✓
VOC Savings	✓X	✓
Noise reduction	✓	✓
Air pollution reduction	✓	✓
Social equity	X	✓
Political acceptability	X	✓X
Improvement in LOS	✓	✓
Efficient redistribution of road capacity	✓	✓
Revenues in the city budget	✓	X
High administrative costs	✓	✓X
Additional transaction costs	✓	✓X
Complicated management and operation system	✓X	✓
Subsidy to more efficient and green transport modes	✓	✓X
Effective to tackle the fluctuated conditions of traffic congestion	✓	✓X
Potential interactions with other instruments	✓	✓

Given the above, the question is whether the solution could be sought in a hybrid policy, which would combine aspects of CP and MC schemes, thus achieving satisfactory level of policy effectiveness and implementability. This

hybrid cordon policy includes a certain number of free entrances to the CZ as in terms of MC scheme, after which users would pay a daily charge for CZ usage, as in terms of CP scheme. The aim of this research is to understand user perspectives, as a central factor in both policy effectiveness and implementability, especially in under-researched context of South-East European cities (Mladenović et al., 2016). In particular, the focus is on understanding users' travel behavior in actual conditions and hypothetical situations, which include a) CP is introduced as daily charge, and b) users are allocated monthly a certain number of mobility credits for free, after which they would pay for CZ access. The proposed scheme differs from the previous ones in the fact that mobility credits - a number of free CZ entries, would not be tradable among users, but unused mobility credits could be replaced by free tickets for recreation and entertainment - such as for example tickets to numerous cultural and sporting events. To this end, the next section provides a summary of the previous research on the acceptability of passenger car access control policies in the CZ, as well as their impact on the transport modal shift. In section three, the research area of the City of Belgrade is described, while section four describes the methodology for analyzing user perspectives. These are followed by the summary of the obtained results, while discussion and directions of future research are outlined in the last section.

## 2. Literature review

Table 2 shows the results of the previous research on the users' willingness of to accept passenger car access control policies in the CZ. From this table, it can be seen that most respondents are not willingness to accept CP. Also, based on previous research, it can be concluded that public support to CP increases significantly after CP implementation. As for the MC policy, no general conclusion can be drawn. In some research, the majority of respondents would support, while in others most of them would not support the MC policy. The reason for this could be found in the fact that users are not sufficiently familiar with this measure and its different designs. In addition, a summary of previous research focused on the effects of passenger car access control policies in the CZ on mode shift is shown in Table 3. These previous results show that the implementation of both CP and MC policies would significantly reduce the share of passenger cars, i.e., increase the share of other transport modes. Thus, despite these policies being rather effective, the underlying challenge of policy implementability remains to be explored further.

Table 2. Users' willingness to accept passenger car access control policies in CZ

Authors	City/ Country	Policy	Method	Results
(O'Mahony et al., 2000)	Dublin (Ireland)	Congestion pricing	Stated preference	45% of respondents supported, while 55% were against CP
(Kockelman & Kalmanje, 2005)	Austin (Texas)	Mobility credits	Stated preference	25% of respondents supported CBCP*
(Bhatt et al., 2008)	London (UK)	Congestion pricing	Revealed preference	Public support before CP implementation was 40%, while after its implementation was 50%
(Eliasson, 2008)	Stockholm (Sweden)	Congestion pricing	Revealed preference	Public support before CP introduction was less than 30%, while after it was 70%
(Liu et al., 2018)	Melbourne (Australia)	Congestion pricing	Stated preference	42% of respondents supported CP, 38% were against, while 20% remained neutral.
(Dogterom et al., 2018)	Beijing (China) Netherlands	Mobility credits	Stated preference	67% and 22% of respondents in China and the Netherlands, respectively, supported TDC**
(Krabbenborg et al., 2020)	Netherlands	Mobility credits	Stated preference	20% of respondents supported TPC***
(Krabbenborg et al., 2021)	Netherlands	Mobility credits	Stated preference	Public support varies from 32% to 52% depending on the TPC*** scheme

Note: \* Credit-based congestion pricing; \*\*Tradable driving credits scheme; \*\*\* Tradable peak credits

Table 3. The effects of passenger car access control policies in CZ on modal shift

Authors	City/ Country	Policy	Method	Results
(Chin, 1996)	Singapore	Congestion pricing	Stated preference	Passenger car trips decreased by 10%, while public transport trips increased by 13%
(Beevers & Carslaw, 2005)	London (UK)	Congestion pricing	Revealed preference	Passenger car and truck trips decreased by 29% and 11%, while taxi and public transport increased by 13% and 20%, respectively
(Leape, 2006)	London	Congestion	Stated	Passenger car, van and truck trips decreased by 34%, 5% and 7%, while

Authors	City/Country	Policy	Method	Results
	(UK)	pricing	preference	taxi, public transport, motorcycle and bicycle trips increased by 22%, 21%, 6% and 28% respectively
(Börjesson & Kristoffersson, 2015)	Gothenburg (Sweden)	Congestion pricing	Stated preference	Passenger car commuting trips and trips with other purpose was reduced by 9% and 7%. Public transport commuting trips increased by 24%, and trips with other purpose was decreased by 8%. Bicycle commuting trips and trips with other purpose decreased by 36%,13%
(Kaida & Kaida, 2015)	Stockholm (Sweden)	Congestion pricing	Stated preference	Passenger car commuting trips decreased by 3.78%, while public transport decreased by 0.35%. On foot and cycling commuting trips increased by 3% and 1%, respectively
(Andersson & Nässén, 2016)	Gothenburg (Sweden)	Congestion pricing	Stated preference	Passenger car traffic decreased by 3.8%, while walking, public transport and bicycle traffic increased by 1%, 2% and 0.9%, respectively.
(Wu et al., 2017)	Beijing (China)	Congestion pricing	Stated preference	CP would increase the usage of public transport by 13%
(Xu & Grant-Muller, 2016)	Beijing (China)	Mobility credits	Stated preference	TC scheme implementation can achieve the goal of reducing the movement of passenger cars by 20.6%
(Dogterom et al., 2018)	the Netherlands	Mobility credits	Stated preference	The reduction in the use of passenger cars is by 20.2% - 24.1%
(Balzer & Leclercq, 2021)	Lyon (France)	Mobility credits	Stated preference	At the optimal level of 200 credits, the public transport ratio increased by 0.18 points, an increase of about 55%

### 3. Study area description – City of Belgrade

With a current population of about 1.7 million, Belgrade, the capital of Serbia, generates about 3.1 million trips per day. According to the latest official data from the 2015 transport model, the largest percentage of trips is performed by public transport system (47.9%). These are followed by private passenger cars (25.7%) and by walking (23.8%). Only 1.3% of the residents travel by bicycle or by motorcycle. According to the data from 2018, public transport system has twelve tram lines, seven trolleybus lines, and eighty-six bus lines, with the total network length is 1,509 km, and the total fleet having 1,198 vehicles. The total length of the bicycle paths currently amounts to only 100 km. The bicycle infrastructure in this city has not been sufficiently developed, and Belgrade does not have a developed shared e-biking and e-scooter system. It should be mentioned that there are two lines of the city railway, and that the Master Plan of the Transport Infrastructure in Belgrade envisages the beginning of the construction of the metro system (ERBD, 2017). The General plan of Belgrade 2021 envisages the construction of a continuous network in the CZ and surrounding municipalities, in the total length of more than 300 km (ERBD, 2017). Due to the fast urban growth and the increased number of passenger cars, which amount to 650 thousand in Belgrade, CZ is increasingly and regularly congested. Here, CZ is a zone defined by the Master Plan of Belgrade (Urban Planning Institute of Belgrade UPIB, 2003), including the old city core, encircled by tram line 2. The area size of CZ Belgrade is 282 ha, with 87,448 inhabitants, thus having high density of residential and workplace locations. The macro location and micro location of the case zone are presented in Fig. 1 and 2.

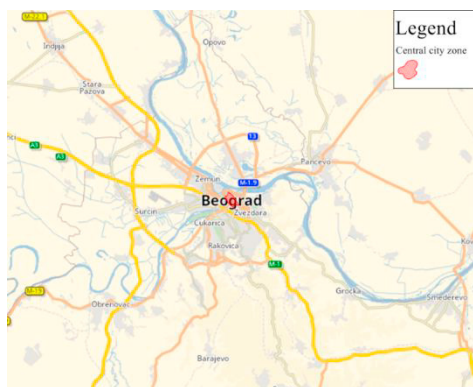


Fig. 1. Macro location of the Belgrade CZ

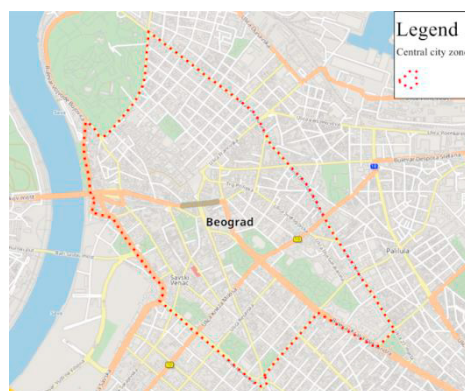


Fig. 2. Micro location of the Belgrade CZ

## 4. Methodology

Users' attitudes were collected using a questionnaire, during January to March 2022. The target group were all Belgrade residents. The questionnaire was sent to certain companies and faculties, as well as student, pensioners and unemployed organizations in Belgrade in order to obtain a representative sample. The questionnaire combined revealed preference questions on the actual travel behavior and stated preference questions, to analyze the users' preferences in defined hypothetical situations. The questionnaire was divided into three sections. The first section contained the questions about socio-demographic and economic characteristics of users. The second section asked about travel patterns of the users' in relation to the CZ. The third part focused on the users' willingness to accept different passenger car access control policies and users' preferences regarding transport mode usage in the case of introducing CP and hybrid scheme in the CZ.

At the beginning of the questionnaire, passenger car access control policies in the CZ were described, including the advantages and disadvantages of these policies. The benefits of passenger car access control policies in the CZ consisted of the following: decrease of traffic congestion, travel time, air pollution, noise, and land occupancy, as well as an increase in users' driving comfort and traffic safety. The main disadvantage of this measure was the fact that passenger car users had to pay a daily charge for the CZ usage, after having used up a limited number of free entries. Also, the users were informed that parking costs would be paid separately as they had been previously. Furthermore, it was pointed out that mobility credits - the number of free entrances to the CZ by passenger cars - could be replaced by certain free tickets for cultural and sports activities. The users would not be able to buy or sell unused MCs to each other, but they would only be able to use the remaining credits for the previously mentioned recreational purposes.

In the questionnaire proper, the respondents were first asked whether they would accept the CP introduction in the Belgrade CZ if a daily charge was RSD150, with RSD117 corresponding to €1. If the respondents gave a negative answer, they were offered 3 free entries per month and a daily charge of RSD150 after exceeding this limited number of entries. If their answer was negative again, they were offered 5 free entries per month and a daily charge of RSD150. Those who would not accept the introduction of this measure were supposed to answer the following question: "Although you are against this measure, which transport mode would you most often use for commuting trips, and which one would you use for trips with other purposes?". The respondents who gave an affirmative answer would then be asked the question "which mode of transport would you use for commuting trips and which for trips with other purposes?". The charge value of RSD150 was estimated on the basis of a detailed analysis of CP charges in other countries, the economic characteristics of Belgrade residents and a pilot study.

## 5. Results

For the purposes of this research, a sample of 655 respondents was collected. In this sample, there were slightly more males (53.7%) than females (46.3%). When it came to age, the most represented category included the respondents aged 25–35 (23.5%). They are followed by those aged 36–45 (20.9%), and those aged 45–55 (18.3%). The largest proportion of the respondents was permanently employed (69.8%). In terms of the average monthly income, most of the respondents had income of €500–750 (24.2%), followed by those with a monthly income of €250–500 (19.7%). Being aware of the fact that all users' categories regarding demographic and socio-economic characteristics were represented in the sample and that they are in accordance with the data of the Statistical Office of the Republic of Serbia, it can be concluded that the sample characteristics correspond to the general characteristics of the Belgrade population. For example, according to the report of the Statistical Office of the Republic of Serbia the average income in Belgrade for 2021 was about €700 and in this research the most of the respondents had income of €500–750 (24.2%).

Table 4 shows positive and negative number of responses and percentages for acceptability of different passenger car access control policies in Belgrade CZ. These results show that the introduction of CP, at a daily charge of RSD150, is supported by 43.21% of respondents, the hybrid scheme (CP + MC) which would include 3 free entries per month by 52.06% of respondents, while the hybrid scheme (CP + MC) which would include 5 free entries on a monthly basis by 54.20% of respondents. The hybrid scheme with 3 free entries per month would lead to an increase in acceptability by 20%, while hybrid scheme with 5 entries per month would generate an increase in 25%, compared to the baseline CP acceptability. Therefore, it can be concluded that the introduction of a hybrid scheme would significantly increase the public acceptability of the passenger car access control policy in the central zone in relation to the CP. In addition,

an important fact is that most respondents would support both cases of the proposed hybrid scheme. This result is logical bearing in mind the fact that the proposed number of free entries by passenger car to central city zone would be enough for most users. Furthermore, the possibility of achieving other benefits for unused mobility credits increased users' acceptability.

Table 4. User's acceptability of different passenger car access control policies in CZ

Passenger car access control in CZ	User's acceptability of different policies			
	No		Yes	
	n	%	n	%
CP: daily charge (RSD150)	372	56.79	283	43.21
Hybrid scheme (CP + MC): -3 free entries monthly + -daily charge (RSD 150)	314	47.94	341	52.06
Hybrid scheme (CP + MC): -5 free entries monthly + -daily charge (RSD 150)	300	45.80	355	54.20

Table 5 shows transport mode usage in revealed behavior and in hypothetical scenarios, separately for commuting and trips with other purposes. Based on the Table 5, it can be observed that the passenger car is currently the most often used mode of transport for commuting trips (47.3%) and for trips for other purposes (41.5%). This is followed by public transport users, since in the case of commuting trips, public transport is used by 39.5% users and 34.8% for trips with other purposes. Next, walking is also present in a significant share - in the case of commuting trips 9.0% and in the case of trips with other purposes 12.7%. All other modes of transport are present in a very small share. In the case of commuting trips, the share of motorcycles, bicycles and electric scooters in the modal distribution is 1.4%, 2.0% and 0.8%, respectively. For trips with other purposes, 2.1% is realized by motorcycle, 6.3% (e)bike and 2.6% by electric scooter. This result is logical having in mind the fact that in the last few years there has been an increase in the motorization rate in Belgrade. Also, the COVID-19 pandemic and the necessity of keeping physical distance caused the reduction of the public transport usage and an increase usage of other transport modes. However, due to insufficient development of cycling infrastructure, lack of e-scooters legislation and the undeveloped shared e-biking and e-scooters system in Belgrade, there is a limited potential for these transport modes.

Results related to hypothetical modal shift from Table 5 show that the introduction of CP, as well as the hybrid scheme, would significantly reduce passenger car usage, especially for commuting trips. For commuting trips, in the case of CP 35.9% of users would use passenger car, while in the hybrid scheme, 36.5% of users would use passenger car. Although both pricing policies would result in about 10% absolute lower use of private cars, there is no significant difference between CP and hybrid scheme for commuting trips. For trips with other purposes, 34.0% would use a car in the case of CP and 37.1% in the case of the hybrid scheme. Thus, the introduction of CP would reduce the absolute share of private car trips by 18% and the hybrid scheme by 11%, compared to actual revealed behavior.

Table 5. Transport mode usage in actual conditions and hypothetical scenarios for commuting trips and trips with other purposes

Transport mode usage	Commuting trips						Trips with other purposes					
	Actual behavior		Hypothetical situation				Actual behavior		Hypothetical situation			
			CP		Hybrid scheme CP + MC*				CP		Hybrid scheme CP + MC*	
	n	%	n	%	n	%	n	%	n	%	n	%
On foot	59	9.0	65	9.9	65	9.9	83	12.7	85	13.0	85	13.0
Bicycle/e-bicycle	13	2.0	29	4.4	28	4.3	41	6.3	51	7.8	48	7.3
E-scooter	5	0.8	17	2.6	17	2.6	17	2.6	19	2.9	21	3.2
Motorcycle	9	1.4	18	2.7	18	2.7	14	2.1	15	2.3	15	2.3
Passenger car	310	47.3	235	35.9	239	36.5	272	41.5	223	34.0	243	37.1
Public transport	259	39.5	291	44.4	288	44.0	228	34.8	262	40.0	243	37.1

\*These results are related to hybrid scheme with 5 free entries on a monthly basis and a daily charge of RSD150

## 6. Conclusion

This research focuses on urban road pricing as an important policy domain for enabling urban sustainability transition. Designing such policy, as part of a larger package of urban transport policies, has to pragmatically look for a fine balance between local context, international lessons, and pricing theory. Although proven effective in both theory and practice, a crucial factor for successful implementation of any road pricing scheme continues to be the lack of public acceptance. Starting with the underlying challenge of public acceptability which relates to perceived equity (Bergquist et al., 2022), we have to recognize that policy design in practice also has to account for other aspects. Those aspects can include understandability of the pricing scheme as well as usefulness of urban road pricing policy as part of larger framework for financing infrastructure. These aspects are of course further challenged by the transforming institutional context in such places as South-East European cities (Mladenović, 2022).

Based on these premises, this research proposed a new cordon hybrid scheme for controlling access to central city zone, combining elements of congestion pricing and mobility credits. Unlike previous mobility credits schemes, this paper proposes a new concept for dealing with unused mobility credits, and does not allow for trading of credits. In this way, the simplicity and avoiding potential abuse of the mobility credit system is ensured, since there is no market for credit exchange among users. The proposed scheme is tested on a case study of central zone of the City of Belgrade. This zone represents the most complex and the most attractive part of Belgrade due to its urban characteristics, building typology, monuments, ambiance and other values. As such, it is an ideal case for testing the challenges of policy acceptability. In this case context, the stated preference method was used to analyze whether the introduction of a hybrid scheme would contribute to higher public acceptance compared to the traditional congestion pricing policy. Also, the impact of the hybrid scheme and congestion pricing policy on the transport mode shift was analyzed.

The findings from questionnaire analysis show that the proposed hybrid scheme has greater public support when compared to the traditional congestion charging scheme. So, from the perspective of policy implementability, public acceptance is higher when considering the hybrid scheme. On the other hand, when talking about policy effectiveness, and in particular modal shift, hybrid scheme does not lead to a significantly higher behavioral change when compared to the traditional congestion charging scheme. This trade-off between implementability and effectiveness, underlines the fundamental dilemma of policy package design (Givoni, 2014). Ultimately, although congestion charging or similar direct taxation policies might be very effective, pragmatic policy design has to sacrifice some of the effectiveness for the sake of implementability.

Future research should consider the effects of a wider range of congestion pricing rates and the number of mobility credits, as well as other policy design details, such as time of day or vehicle occupancy, or relation to parking and overall mobility service pricing (Simićević et al. 2012; Liimatainen & Mladenović, 2018). This analysis requires supporting exploration of underlying factors that are affecting policy implementability and effectiveness, such as user self-perception, revealed transport poverty or institutional obstacles. These factors can be integrated into a decision-support framework for policy design (Milenković et al., 2018), while further understanding the environmental and economic footprint (Ramandanis et al. 2020). Finally, research supporting policy packaging efforts in practice should understand the aspects of political dynamics and support participation in policy design processes.

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