FROM URBAN CONGESTION PRICING TO TRADABLE MOBILITY CREDITS: A REVIEW

Siyu Li
Department of Civil and Environmental Engineering, Universitat Politècnica de Catalunya, Barcelona, Spain
Francesc Robusté
Department of Civil and Environmental Engineering, Universitat Politècnica de Catalunya, Barcelona, Spain

ABSTRACT

Congestion is still a big challenge for urban mobility while vehicle sharing, eCommerce and autonomous vehicles will likely increase the unit veh-km of each vehicle and the density of vehicles moving on the streets. Urban vehicle congestion pricing schemes have been taken as effective solutions to this problem. This paper first reviews the research and application cases of urban congestion pricing through recent years, although with the well-developed theoretical basis and successful practices in Singapore, London, Stockholm, Milan, etc., public acceptance and equity concerns are still the main issues for such policies' implementation. To circumvent this shortcomings of congestion pricing, a scheme of tradable mobility credits is proposed as an alternative. As travellers are distributed mobility credits within a specific urban area, which are allowed to be traded, those with low vehicle-using demands can sell their credits to those with more demands. Therefore with this scheme, people have the incentive to reduce the using of vehicles. This paper reviews the studies on this new urban mobility management strategy and compared it with ordinary congestion pricing schemes. Finally, we conclude the gap and possible directions for future work in this area.

1. INTRODUCTION

Congestion has been the major problem that troubles cities around the world. As a strategy of Transportation System Management, urban congestion pricing (CP) was carried out as the approach to solve it. Since the early introduction by Pigou (1920) and Knight (1924), it has long been taken as the most socially optimal strategy for the allocation of road capacity (Hau, 2005). For road bottlenecks or urban restriction area, vehicles enter or travel within the area will be levied. Especially in recent decades, theories and technologies have been well developed and several cities have practised their urban charge schemes.

However, although there are existences of successful applications, arguments on the implementation of CP schemes never stop. Public acceptance is the main obstacle while the equity problem is often considered the core. Thus, the tradable mobility credits (TMC) scheme is introduced to make up for this shortcoming. It is seen as an alternative to the CP but allow travellers to drive for free with limited quotas. Such schemes of tradable credits or tradable permits are found studies and implementations in various fields like forestry regulation (Tripp & Dudek, 1989), water pollution control (Dales, 1968), automobile emission control (Goddard, 1997; Raux & Marlot, 2005) and the well-known Emission Trading Scheme (ETS) of EU, etc.

Both CP and TMC have gained enough attention, there are still difficulties and unresolved issues. Especially the newer TMC, though theoretical works have been carried out, practical experiences are not seen. This paper aims to present, via a case study of urban congestion pricing and an overview of TMC, valuable insights on the further development of TMC to make it more applicable for future implementation.

The paper is structured as follows. Section 2 reviews the implementation cases of urban congestion pricing in Singapore, London, Stockholm and Milan. Then this part also discusses the arguments on acceptance of CP. Section 3 reviews the development, theory and recent works of TMC schemes. Finally, section 4 concludes the paper and proposes further research direction on this area.

2. URBAN CONGESTION PRICING

The main principle of CP is to charge the externalities that are imposed on other users by a new driver entering the network (Knight, 1924; Pigou, 1920). In this case, the equilibrium will achieve when the charging price is equal to the marginal cost of other users. After decades of development, the research of CP has already been well developed. Detailed reviews on theories and methodologies have been concluded (de Palma & Lindsey, 2011; Tsekeris & Voß, 2009; Yang & Huang, 2005). As a transportation demand management policy, CP leads travellers to change their travel behaviours (including route choice, travel time, mode choice, et al.), reallocate the road to travellers who are willing to pay for the externalities. Besides, CP can raise revenues to fund transport projects like road maintenance and the improvement of public transport. Therefore it is approved by most economists (Lindsey, 2006) to achieve social optimum. With sufficient theoretical support, various CP schemes have been considered or already implemented worldwide.

2.1 Implementation cases

Several urban areas around the world have implemented urban congestion schemes to alleviate congestion in the city centres, including Singapore (1975), several Norwegian cities (Bergen, Oslo, Trondheim, etc.), London (2003), Stockholm (2006), Milan (2012) and Gothenburg (2013). The charging schemes vary among those cities with their unique features. All those practices show efficient consequences on congestion control.

Here, based on literature, we selected Singapore, London, Stockholm and Milan to investigate their CP schemes and impacts.

2.1.1 Singapore

As the first practice, Singapore implemented the Area Licensing Scheme (ALS) in 1975. This is a manual-enforced cordon toll system based on gantries at entry points of Restricted Zone (RZ) of the city centre. Drivers needed to buy licenses in advance to enter and travel within the central area, during morning peak hours from 7:30 to 9:30 am. Then three weeks after the introduction, the morning charging hours were extended to 10:15 am to response to the occurring traffic just after 9:30 am (Fan et al., 1992). And initially, they thought that the restriction of morning peak hours would show a 'mirror image' on the evening outbound traffic, so there was not charging for evening peak hours. However, as such image did not materialize, ALS is added to the evening peak from 4:30 pm to 7:30 pm (Phang & Toh, 2004) in 1989. Finally in 1994, in order to make the traffic more even throughout the day, ALS was extended to the inter-peak period (10:15 am to 4:30 pm) but with a lower charging rate. In addition, another Road Pricing Scheme (RPS) was implemented to three expressways.

However, the effect of ALS was far above expectation and was considered to make the road network underutilized (Santos, 2005). After the introduction of ALS, the average speeds within the RZ increased to 36 km/h while the expectation was 20-30 km/h (Phang & Toh, 1997). And the peak-hour traffic flow reduced by 45-50% while the original target of reduction was 20-30% (Phang & Toh, 2004). In that case, McCarthy & Tay (1993) argued that the charging rate of ALS was about 50% above the optimal level. Similar conclusions were made after the implementation of the new Electronic Road Pricing scheme (Li, 1999; Willoughby, 2000).

In 1998, ALS and RPS were replaced by Electronic Road Pricing (ERP). This new system made the charging scheme more convenient for both drivers and the administration department. Drivers do not need to buy various licenses in advance, instead, an In-vehicle Unit (IU) is installed on the windscreen of each vehicle with a stored-value card. With sensors on the gantries at each entrance of RZ and IUs on vehicles, ERP charges vehicles when they pass the gantries. The ERP system based on the rationale of optimal average speeds. The optimal average speed for expressway should be 45-65 km/h while 20-30 km/h for arterial roads. The rates and charges are reviewed every quarter and set in 30-minute blocks which means that the rates can be differentiated regarding the real-time congestion level. That means the charge will be reduced if the average road speeds are higher than the optimal level and vice versa (Goh, 2002; Yap, 2005).

On the other hand, alongside the ALS and ERP, Singapore was also developing its public transit services as the alternative for mobility (Santos, 2005). Commuters shifted from private vehicles to public transport modes. The share of public transport increased from 33% to 69% (Phang & Toh, 2004).

2.1.2 London

Following Singapore and several Norwegian cities, London introduced its Congestion Charge scheme in February 2003. It's a kind of area licensing scheme (Santos & Shaffer, 2004). During weekdays between 7:00 am and 6:30 pm, drivers needed to pay a fee (£5 initially) in advance to travel within the central area delimited by the Inner Ring Road. Once paid, drivers can pass the cordon with unlimited journeys in a single day. Although the heavy goods vehicles were charged three times the normal charge (£15) at the beginning, now the price is the same, regardless of the vehicle types and entry time. Meanwhile, there are exemptions and discounts for several specific kinds of vehicles. For example, vehicles belonging to the residents of the central area enjoy a 90 percent discount. Then in 2007, the Congestion Charge zone was extended, making the total Congestion Charge zone covers 39 km^2. Now the congestion charge has been extended to the entire week, a £15 daily charge is asked from 7:00 am to 10:00 pm to travel within the Congestion Charge zone (except Christmas Day).

Before the implementation of Congestion Charge, traffic within the charging zone was expected to reduce by 20 to 30 percent (TfL, 2003) and average speeds would increase by 10 to 15 percent (Santos, 2008). Several months after, the number of private cars, vans and trucks in the central area dropped by 27 percent (Leape, 2006). In terms of average speeds in central London, it was around 14 km/h in 2002 (TfL, 2003), in comparison with 16 to 17 km/h after the implementation (TfL, 2004).

Alongside the Congestion Charge scheme, London has put investment in public transport sectors, promoting the network, convenience and the level of service (Givoni, 2012; Santos, 2008). This reuse of revenues helped it to increase public acceptance and attracted 50 percent of the former vehicle users to shift to public transportation.

2.1.3 Stockholm

In 2016, Stockholm carried out its CP scheme as a seven-month trial from January to July. It was a time-differentiated charge scheme with the cordon around the inner city of Stockholm. Like ERP of Singapore, charges are made once vehicles pass the border. Then after evaluation of the trial and a referendum, the scheme has been permanently implemented since August 2007.

Vehicles would be levied SEK 10, 15 or 20 (depending on the time of day) when passed the cordon on weekdays from 6:30 am to 18:30 pm. There were not levies in evenings and holidays as well as free for vehicles to cross the charging area through the Essinge Bypass. Meanwhile, around 30% of vehicles were exemptions including buses and alternative-fuel cars (Eliasson, 2008). The target was a reduction of 10 to 15 percent of traffic across the cordon. As a result, compared with the corresponding months of 2005, every month the number of vehicles that passed the border decreased 20 to 30 percent in the trial period (Eliasson et al., 2009).

The most interesting point of Stockholm is the change of public acceptance. Before the trial, only 36 percent of Stockholm citizens were in favour of the CP scheme. Then public acceptance increased gradually after the implementation. Later in September 2006, the referendum showed that 53 percent of voters supported to remain the charging scheme (Borjesson et al., 2012; Eliasson, 2014). However, the oppositions of the citizens live in the suburban areas outside Stockholm did not gained enough consideration.

The revenues collected were dedicated to public transport during the trial. As Menon & Guttikunda (2010) pointed out, like Singapore and London, the success of the implementations of CP in Stockholm is partly attributed to their well-developed public transit systems. Similarly, Kottenhoff & Brundell Freij (2009) pointed out that, the successful implantation of CP in Stockholm is closely linked to the expansion of the public transport system.

2.1.4 Milan

Milan first implemented an urban vehicle charge scheme called Ecopass in 2008. But the difference from other cases is that it was a traffic pollution charge while congestion reduction just a side-goal. The charge was set based on the Euro emission standards. A daily charge was imposed on vehicles enter the traffic restricted zone between 7:30 am and 7:30 pm. The maximum fee was €10 while different levels of discounts were granted to low-emission vehicles and frequent users (Rotaris et al., 2010). This scheme made owners of Euro 0-3 vehicles shift to other low-emission vehicles and led to a substantial increase in motorbikes (Percoco, 2014).

The Ecopass program terminated by the end of 2011 and then, was replaced by a new congestion control scheme (Area C) from January 2012. The new Area C scheme has the same charging zone, technology and time period as former Ecopass. As Area C is a congestion charge instead of a pollution charge, vehicles are imposed the same €5 daily charge regardless of their emission standard. And in order to increase acceptance, residents who live within the area have 40 free entrance per month and need to pay €2 for every extra entrance while commercial vehicles also benefit from discounts (Beria, 2016).

After the implementation of Ecopass, commercial and private traffic showed a reduction of 16.2 percent in 2010, compared to 2007. The daily average emission of PM10 decreased by 25 percent within the area. However, in four years, the environmental-friendly vehicles entering increased by 478 percent and commercial vehicles increased by 1400 percent. Then as the impacts of Area C, traffic volume reduced by 36 percent while PM 10 emission reduced by 27 percent (Martino, 2011).

In terms of the use of revenues collected by the schemes, unlike the Ecopass was criticized for its lack of transparency on the revenue reinvestment, in Area C they reinvested the revenues to improve public transport and sustainable mobility modes (Beria, 2016).

2.1.5 Cases summary

These cases prove the effectiveness of such CP schemes on urban congestion control and the successful result gained the endorsement of citizens. One thing that needs to point out is that, although all four cases of CP schemes charge vehicles at the entrance of charging areas, they are different (Croci, 2016; Gu et al., 2018). Singapore and Stockholm use cordon-based schemes that make charges as long as vehicles pass the borders. London and Milan use the kind of area-licensing scheme or called zonal schemes that collect daily charge that vehicles can enter the area with unlimited times.

These four successful cases have a common feature is that the approach of CP is just one of a basket of policies to manage congestion. Another important point is the investment in alternative transport modes, especially public transport. Kottenhoff & Brundell Freij (2009) concluded that public transport may serve very necessary roles in CP policy package. Sole CP schemes will change the drivers' route and travel time to show the reduction of traffic during peak-hour windows (Santos, 2005) while The development of public transport system can help reduce the use of vehicles and attract the mode shifting. The reinvestment of revenues on public transport can benefit the equity issue as well (Eliasson & Mattsson, 2006). Revenue distribution is considered as one of the auxiliary amendments of CP to deal with inequality and make the policy more acceptable (Tian, 2015).

Furthermore, discounts and exemptions are important. For instance, in London citizens living in the city centre enjoy a 90 percent of discount and in Singapore vehicles with more than three passengers also have a discount. And disabled people are considered exemptions in implementations. Moreover, Gu et al. (2018) stated that, in order to achieve a theoretically efficient pricing scheme, the simplicity of the policies is important. The failure in Edinburgh and the greater Manchester showed people's dislike of complicated mechanisms. The ERP is much more simple than ALS that drivers do not need to buy tickets in advance any more. While in Milan, the replacement of Ecopass by the single-rate Area C helped it to raise public acceptance (Hensher & Li, 2013).

2.2 Public acceptance

However, although with sufficient theoretical studies, urban congestion pricing schemes can only find limited practical applications across the world. The main obstacle to the implementation of CP is public acceptance (Albalate & Bel, 2009; Banister, 2003; Glazer & Niskanen, 2000; Schade & Schlag, 2003). Citizens have long taken the free use of roads for granted. Naturally, it is difficult to gain public acceptance to charge a good which is always for free. Cities including Hong Kong, New York, Edinburg and Manchester are the cases that failed to introduce CP schemes (Albalate & Bel, 2009; Gu et al., 2018). Even in

Stockholm's referendum, they ignored the opposition from suburban areas where residents rely more on vehicles to commute to the urban centre.

On the other hand, equity is greatly concerned by stakeholders (Perera & Thompson, 2020) and is taken as the core of acceptance (Langmyhr, 1997; Viegas, 2001), as this is strongly related to the perception of fairness. People tend to take CP as an extra tax on drivers. And it makes low-income drivers gave the roads to those with higher income or have high value of time (VOT). Meanwhile, if the revenues are not used to improve the public transport system, those low-income drivers would be the victims of CP.

In the context of out-of-pocket charges, low-income drivers and people with reduced mobility are faced with more severe travelling burden and further limitations on the travel options (Gu, et al., 2018; Weinstein & Sciara, 2006). Therefore, in London, Stockholm and Milan there are various discounts for some specific groups. Referring to a review article focusing on public acceptance (Gu. Et al., 2018), it concludes that all of the selected key references mention that in Hong Kong, New York and Edinburg, the design of CP policies ignored the equity problem and therefore the concerns of inequity became the main reason for people's opposition (Larson & Sasanuma, 2010; Pretty, 1988; Ryley & Gjersoe, 2006). Accordingly, a more acceptable and fairer approach is needed.

3. TRADABLE MOBILITY CREDITS

3.1 Early works

In order to tackle the most concerned equity problem of CP, a kind of schemes based on tradable mobility credits are proposed as an alternative (Fiorello, 2010; Gulipalli et al., 2008; Raux, 2004; Zhang et al., 2021). The general concept is simple. Drivers are allocated with a limited amount of mobility credits during a certain period (e.g. one month). When travelling within a charging area or go through a charge cordon, drivers will be charged the credits rather than out-of-pocket monetary. Those who exhaust the credits need to buy from authorities or from other drivers. Tian (2015) described it as a stick-carrot mixed approach while traditional CP was seen as the stick. In this situation, drivers with low VOTs have the incentive to reduce their use of vehicles and get a bonus by selling their surplus credits while those with higher VOTs will pay for the congestion externalities.

In the field of congestion control, mobility credits or mobility rights are not a new concept. Daganzo (1995) proposed a hybrid scheme of rationing and pricing. This scheme can be seen as the allocation of mobility quotas without tradability. Viegas (2001) used the concept of "mobility rights" to deliberate over the quota scheme. He described that, at present, drivers get unlimited quotas of mobility rights to drive and the free allocation of limited quotas could be seen as a reduction of the current situation.

Early research mainly focused on concept development, policy design, qualitative analysis and discuss the potential of implementation and reactions from stakeholders. To tackle congestion externalities, Verhoef et al. (1997) proposed several different types of tradable permits schemes which are based on ownership, distance, fuel consumption or parking, respectively.

Then the idea of TMC is proposed more definitely. Raux (2004) discussed the applications of transferable permits in the field of transport policy. He stated that such transferable permits could be an intermediate solution for congestion problems. Later he further defined the tradable driving rights (TDR) scheme with which that urban inhabitants are allocated certain quotas of driving rights and allowed to trade their unused quotas with those who need excessive trips (Raux, 2007). In parallel, Kockelman & Kalmanje (2005) designed a revenue-neutral credit-based congestion pricing (CBCP) policy. Registered vehicle owners get a monthly monetary allowance of travel credits. Drivers do not need to pay money unless they use out of the credits and those who with unused credits can stock up for next month or exchange for cash. And the further work based on expert surveys gave a more detailed refinement of CBCP policy (Gulipalli et al., 2008). From the user's point of view, CBCP is a very simple scheme since users only need to interact with the authority. Studies on public acceptance have shown that the simplicity of CP policies is another key factor (Gu et al., 2018), which gains proof from the rejection of Edinburgh and Manchester (Hensher & Li, 2013). Ch'ng (2010) hypothesized a tradable credits system with a two-sided auction market where the price of mobility credits is determined by demand and supply. Based on an experiment of tradable credits auction, he explored that trading in the auction market allows revenues to be returned to drivers who shift to other alternative modes and the equilibrium of utility among both sellers and buyers will be achieved.

In general, the TMC schemes have the features as below:
1) the administration department determines the total amount of credits and allocates them to eligible individuals;
2) the exchange of credits is allowed: individuals that travel less can sell their credits to those who exhaust the credits;
3) like congestion pricing schemes, the charging rates of mobility credits may vary depending on the time, location, route or vehicle type.

3.2 Quantitative studies and development

The idea of such a scheme is simple but deeper works more than conceptual discussions are needed. In the recent decade with the well-developed concepts, investigations started to concentrate more on quantitative studies.

Fiorello et al. (2010) took Genoa as a case study, developed a system dynamic model of Genoa Mobility Rights (GMR) to estimate the impact of TMC on individuals with a sequential procedure. Yang & Wang (2011) introduced a system of tradable travel credits and developed the quantitative analysis as well as modelling of the scheme. They assumed a situation with homogeneous travellers to trade their travel credits in a free and competitive market without the interference of the government. After that, they further investigated the complicated situation of heterogeneous drivers that have different VOTs (Wang et al., 2012). Then more following works contribute to the scenario of heterogeneous users. In order to promote a more equitable TMC scheme, Wu et al. (2012) developed a modelling framework to reckon the impacts of the distribution of credits on travellers with different income and geographic features. He et al. (2013) state that the authority needs to deal with not only individual travellers but also transportation firms (such as logistic companies and transit agencies). They take individual travellers as Wardrop-equilibrium (WE) players while transportation firms as Cournot-Nash (CN) players. The differentiated scheme will allocate different numbers of credits to these kinds of users and also charge them differently. Zhu et al. (2014) assumed travellers with continuously distributed VOTs and established a scheme that can decentralize a given target network flow pattern into a user equilibrium link flow pattern. They stated that a proper credits distribution regulation can make every heterogeneous traveller better off.

In the recent years, the increasing number of articles are seen in this field. Nie & Yin (2013) designed a new TMC scheme that rewards credits to travellers who avoid peak-hour window or choose other alternative modes. Their work assigns that not only the new scheme but even a very simple TMC scheme can achieve substantial efficiency. Miralinaghi & Peeta (2016) proposed a multi-period TMC scheme that travellers are allowed to use or sell the credits in the current period or transfer to future periods. They argue that this scheme can stabilize the price of credits. Xiao et al. (2019) proposed a link-based cyclic tradable credit scheme (CTCS) in which the compensatory credits could be charged from or subsidized to the travellers. In terms of sustainable-oriented transport, Wang et al. (2020) combined the TMC scheme with a link capacity improvement measure and proposed a bi-objective bi-level model to balance economic growth and environmental management.

In addition, the efficiency and effectiveness of TMC for alleviating bottleneck congestion are discussed (Tian et al., 2013; Xiao et al., 2013). Nie (2015) carried out a tradable credit scheme of road bottleneck during the morning peak period. He assumed that vehicles passing the bottleneck within the morning-peak time window would be charged with credits and on the contrary, off-peak travellers would be rewarded with tradable credits.

Meanwhile, as a transportation system management policy, participants' reaction and behaviour are important. Ye & Yang (2013) established a continuous dynamic model to depict travellers' learning behaviour. Bao et al. (2014) adopted a disutility function to study travellers' loss aversion behaviour for credit collection during route choice procedure. Xu & Grant-Muller (2016) captured simulation analysis for a case study of Beijing to appraise the TMC's influence on people's mode choice and travel pattern. Tian et al. (2019), based on an online experiment, studied people's interaction with each other as well as with intelligent virtual agents in the situations of credit trading and route choice. And a more detailed literature review on the behavioural impact of tradable credits is concluded by Dogterom et al. (2017).

And necessarily, in terms of the issue of public acceptance, TMC gains better support from the public. The work by Kockelman and Kalmanje (2005) in Austin, Texas proved TMC as a viable and competitive alternative. Likewise, a survey carried out in the UK revealed the better public acceptance of TMC than CP and participants approved its fairness (Harwatt et al., 2011). Dogterom et al. (2018) investigated the acceptability of a distance-based TMC scheme in the Netherlands and Beijing. They found that TMC gained a much higher acceptance in Beijing in comparison with the Netherlands and attributed it to the worse congestion problem.

3.3 Current problems

TMC is a new congestion management approach and there have not found practical implementations by now. Some issues still need more insights.

The administrative cost is a main issue that researchers concern about for TMC. Authorities need to work on the verification of eligible receivers, allocation of credits, monitoring the use and transaction, etc. Therefore, the administrative cost of TMC scheme will be higher than ordinary CP schemes (Dobes, 1998; Fan & Jiang, 2013; Nie, 2012; Verhoef et al., 1997). Especially the transaction cost is a new matter that needs to be taken into consideration but by now have not gained enough attention. Nie (2012) investigated the effects of transaction cost on auction market and negotiated market respectively. He assumed a brokerage service to assist the transaction procedures and a commission fee is charged. They concluded that the auction market can achieve the desired equilibrium allocation of mobility credits while in negotiated market transaction costs would influence the equilibrium. He et al. (2013) concluded that transaction costs will reduce the trading volume of mobility credits and change the price as well as the travellers' route choices. Zhang et al. (2021) found that transaction cost can lead negative influence on travel disutility for people with low VOT and suggested the imposition of equity constraint in TMC design.

Additionally, TMC is introduced as an alternative to CP. While the distribution of revenues on the development of alternative mobility modes is widely approbated in CP schemes, in TMC there are not enough insights. Revenues could be collected as a commission fee in the free-market schemes or collected directly in the schemes like CBCP. In fact, CBCP may be much convenient for the administration department to redistribute the bonus to drivers and to other transport projects. Authorities need to balance the proportion of revenues that rewarding drivers and investing in transport projects, as well as administrative cost should be considered.

Another issue is that researchers now have not reached a consensus about the credit receivers. In general, we can divide the objects into two groups. One is a more limited group that only referred to drivers or car owners (Ch'ng, 2010; Kockelman & Kalmanje, 2005; Verhoef, 1997). On the contrary, other researchers argue that mobility credits should be allocated to all taxpayers or local inhabitants (Fiorello, 2010; Raux, 2007; Viegas, 2001; Yang & Wang, 2011). A consensus is that credits should be allotted to individuals rather than vehicles. Viegas (2001) pointed out that allotting the credits to vehicles will induce rich drivers to own more cars. It is important to determine the appropriate TMC users which are highly relevant to the quantification of the total amount of credits. If the system adopts a free trade market or the auction scheme for transaction, the trading price will be influenced by the total amount. On the other hand, the number of participants in the system will partly determine the efficiency and cost of administration and trading.

4. CONCLUSIONS

In this article, starting from urban congestion pricing, we have reviewed the successful experience of the implantations in Singapore, London, Stockholm and Milan while the failure cases are also discussed. Sufficient research works and practical cases have shown that public acceptance is the main obstacle for the implementation of CP schemes and the core factor should be equity. Thus, we review the literature on TMC schemes, which was proposed as a fairer congestion management approach to circumvent the shortcoming of CP. Although plentiful conceptual, qualitative and quantitative works have been carried out, there are currently lack of implementation practices of TMC schemes. The TMC presents more complicated management and operation systems than traditional CP schemes. Taking the cases of CP as a reference, future research is recommended to improve TMC schemes more applicable.

First, more specific work can be done in terms of heterogeneous users. The feedbacks of those cases show that commercial, retail and delivery industries enjoy the smooth traffic in urban areas that benefit from the implementation of CP schemes. The abatement of congestion, especially during peak-hour windows, allows the delivery industry to arrange their schedule more flexible. More importantly, while with frequent trips and larger size, urban freight vehicles contribute more to urban congestion. Therefore, in the scenario of heterogeneous users, future works of TMC could draw more attention on urban freight delivery. Setting different regulation of credit consumption that vary from vehicles types to present the externalities caused by freight delivery vehicles.

Secondly, the reuse of revenues on the development of public transport system (Banister, 2003) or active transport modes is essential. As drivers shift from private vehicle to other means of transport like public transport (metro, commuter rail, bus, etc.) and active transport (bicycle, walking and PMDs), the services of these modes should be promoted. Hence, further research can focus on the balance of the bonus enjoyed by individuals and the revenues invested in transport projects.

Besides, researchers could also do further investigation on the allocation process of credits, including more insights on the determination of eligible receivers and the total number of credits. The quantitation of the total amount of credits in the urban area is crucial for the theory's implementation.

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