Tradable Mobility Credits Taking the Place of Congestion Pricing: An Overview

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ABSTRACT

While car sharing, eCommerce, and autonomous vehicles are expected to increase the unit veh-km of each vehicle as well as the density of vehicles moving on the streets, congestion remains a big barrier to overcome in urban transportation. Plans to charge for urban car congestion have been viewed as successful solutions to this issue. Although urban congestion pricing has a solid theoretical foundation and has been successfully implemented in places like Singapore, London, Stockholm, Milan, etc., public acceptance and equity concerns remain the main obstacles to its implementation. This paper first reviews the research and application cases of urban congestion pricing through recent years. An alternative to congestion pricing that gets around its drawbacks is a system of transferable mobility credits. Others with low vehicle-use demands can sell their mobility credits to people with higher demands since travelers are given mobility credits that can be transferred within a particular urban region. So, this program gives people the chance to cut down on their use of cars. This paper highlights the studies on this innovative approach to urban mobility management and contrasts it with traditional congestion pricing programs. Finally, a conclusion has been drawn on the gap and some potential directions for further research have been suggested.

Keywords: Traffic congestion; Congestion pricing; Tradable mobility credits, Value of time.

INTRODUCTION

Cities all around the world have been troubled by congestion as their main issue. Urban congestion pricing (CP), a method of managing the transportation system, was used as a solution. It has been regarded for a long time as the most socially optimal technique for the allocation of road capacity since its early introduction by Pigou (1920) and Knight (1924). Vehicle entry and exit fees apply when entering or leaving an urban limitation area (Hau, 2005). Particularly in recent decades, theories and technologies have advanced significantly, and many cities have put their urban charge systems into effect. Despite the existence of successful applications, debates on the adoption of CP schemes never end. While the equity issue is frequently thought of as the core, public acceptance is the key barrier. To make up for this deficiency, the tradable mobility credits (TMC) program is developed. It is seen as a substitute for the CP but permits travelers to drive for free with certain restrictions. Studies and applications of these tradable credit schemes can be found in many different sectors. The European Union's Emission Trading Scheme ought to be the most well-known.

Despite the attention that both CP and TMC have received, there are still problems and unresolved issues. Even while theoretical work has been done, particularly with regard to the more recent TMC, no real experiences have been reported. This paper seeks to provide important insights on the future development of TMC to make it more appropriate for implementation through a case study of urban congestion pricing and an overview of TMC.

The paper is structured as follows. The implementation of urban congestion pricing in Singapore, London, Stockholm, and Milan is examined in Section 2. The reasons for and against public acceptance of CP schemes are then covered in this section. The development, theory, and most recent works on TMC systems are reviewed in Section 3. Section 4 closes the essay and suggests a course for further research in this area.

Urban congestion pricing

The fundamental idea behind CP is to make users pay for any externalities that a new driver introduces to the network (Knight, 1924; Pigou, 1920). When the cost of other users' marginal costs is equal to the charging price in this situation, equilibrium will be reached. The research on CP has advanced significantly after decades of development. Theoretical and methodological reviews that are in-depth have been completed (de Palma and Lindsey, 2011, Tsekeris and Voß, 2009, Yang and Huang, 2005). As a strategy for managing transportation demand, CP encourages users to alter their travel habits and reallocates space on the road to users willing to shoulder the costs of externalities. Additionally, CP can generate income to pay for transportation initiatives like road maintenance and the expansion of public transportation. Thus, such a Scheme is supported by the majority of economists to achieve social perfection (Lindsey, 2006).

Implementation cases

Several urban areas around the world have implemented urban congestion pricing 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). Although 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.

Singapore

The Area Licensing Scheme (ALS) was introduced in Singapore in 1975. This was a manually enforced cordon toll system that used gantries at Restricted Zone (RZ) entry points. During the morning rush hour from 7:30 to 9:30 am, drivers were required to purchase licenses in advance in order to enter and move about the core region. In response to the prevailing traffic right after 9:30 am, the charging hours were increased three weeks following the launch to 10:15 am (Fan et al., 1992). In the beginning, there was no charge for evening peak hours since it was believed that the limit of morning peak hours would create a "mirror image" of the evening outbound traffic. ALS was added to the evening peak in 1989 from 4:30 pm to 7:30 pm (Phang and Toh, 2004) due to the fact that such an image did not develop. Finally, in 1994, ALS was extended to the off-peak hour with a lower charge rate in an effort to balance out the volume of traffic throughout the day. But ALS was thought to make the road network underused (Santos, 2005). Following the introduction, average RZ speeds jumped to 36 km/h, compared to expectations of 20–30 km/h. And whereas the initial aim was 20-30%, the peak-hour traffic volume decreased by 45-50%. (Phang and Toh, 2004). The pricing rate, according to McCarthy and Tay (1993), was nearly 50% more than it should have been.

Electronic Road Pricing (ERP), which took the place of ALS in 1998, improved the charging system's convenience and effectiveness. Nowadays, each vehicle has an in-vehicle unit fitted on the windscreen that is operated by a stored-value card, eliminating the need for drivers to purchase multiple licenses in advance. In addition, the sensors installed on the gantries at each entry to RZ allow ERP to assess a fee to cars as they pass through the gantries. The ERP system is built around the idea of ideal average speeds. The ideal average speed for expressways should be 45–65 km/h, while for arterial routes it should be 20–30 km/h. The rates and charges are reevaluated every three months and are established in 30-minute increments, allowing for differentiation of the fees based on the level of current congestion. Therefore, if the average road speed exceeds the ideal level, the fee will be lowered, and vice versa (Goh, 2002; Yap, 2005). Singapore, however, develops its public transportation services in addition to its pricing (Santos, 2005). The percentage of commuters using public transportation rose from 33% to 69% as they switched from driving private cars (Phang and Toh, 2004).

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London

London's Congestion Charge program was launched in 2003, following the introductions of Singapore and numerous Norwegian cities. It resembles an area licensing system (Santos and Shaffer, 2004). Drivers had to pay a fee in advance to travel inside the central area bounded by the Inner Ring Road on weekdays between 7:00 am and 6:30 pm. After paying, drivers are permitted an unlimited number of trips across the cordon each day. The initial price for big freight vehicles was three times the standard rate. Exemptions and discounts are offered in the meantime. For instance, inhabitants of the core area receive a 90% discount on their autos. The Congestion Charge zone was then expanded in 2007 to encompass an entire 39 km2. Now that the Congestion Charge is in effect every day of the week, a flat daily fee is required to enter the Congestion Charge zone from 7:00 am to 10:00 pm, regardless of the kind of vehicle or entrance time.

Prior to the introduction of the congestion charge, it was anticipated that average speeds would rise by 10% to 15% and traffic within the pricing zone would decrease by 20% to 30%. Several months later, traffic decreased by 27% and average speeds increased from 14 to 17 kilometers per hour (TfL, 2003 and 2004). Along with the congestion charge program, London has made investments in the public transportation industry to improve the network, convenience, and level of service (Givoni, 2012; Santos, 2008). This reusing of money makes it more popular with the public, and it got 50% of the people who used to drive to switch to public transportation.

Stockholm

Stockholm tested their CP program for seven months in 2006. It was a time-differentiated fee plan with a cordon around Stockholm's central business district. Once a vehicle crosses the border, charges are applied. After a vote and trial review, the program has been in place permanently since August 2007. On weekdays from 6:30 am to 17:30 pm, vehicles would be assessed (the fee varies depending on the time of day) for passing the cordon. Buses and alternative-fuel vehicles were among the approximately 30% of vehicles that were excluded (Eliasson, 2008). The goal was to reduce traffic across the cordon by 10% to 15%. As a result, every month of the testing period, fewer vehicles crossed the border than in the corresponding months of 2005. (Eliasson et al., 2009). The change in public acceptability is Stockholm's most intriguing feature. Only 36% of Stockholm residents supported the CP system prior to the trial. After the implementation, approval by the general public progressively increased. A later referendum in September 2006 revealed that 53% of voters preferred to keep the fee system in place (Borjesson et al., 2012).

During the trial, public transportation was supported by the gathered funds. Like in Singapore and London, Stockholm's deployment of CP has been a success in part due to its well-developed public transportation system (Kottenhoff and Brundell Freij, 2009; Menon and Guttikunda 2010).

Milan

In 2008, Milan became the first Italian city to deploy an urban vehicle fee system called Ecopass. Although congestion mitigation was just a secondary purpose, this case differed from others in that it involved a traffic pollution charge. Based on the Euro emission criteria, the fee was determined. Vehicles entering the zone with restricted traffic between 7:30 am and 7:30 pm had to pay a daily fee. Low-emission vehicles and regular users received various levels of discounts (Rotaris et al., 2010). By the end of 2011, the Ecopass program had been discontinued, and Area C had taken its place. The charging zone, technology, and time frame of the new Area C scheme are identical to those of the previous Ecopass. Vehicles are subject to the same daily fee regardless of their emission criteria because Area C is a congestion charge rather than a pollution levy. In addition, in order to encourage more people to use the service, citizens who live within the area are given forty free entry per month; however, they are required to pay for any more excursions, and commercial cars were eligible for discounts (Beria, 2016).

Commercial and private traffic decreased by 16.2% in 2010 compared to 2007 after the introduction of Ecopass. Within the region, the daily average PM10 emission was reduced by 25%. However, commercial vehicles grew by 1400% and environmentally friendly vehicles increased by 478% during the course of four years. Following Area C's effects, traffic volume decreased by 36% and PM10 emissions by 27%. (Martino, 2011). Regarding the revenues, Area C was praised for its transparent income reinvestment practices, in contrast to the Ecopass, which received criticism for its lack of transparency (Beria, 2016).

Cases summary

These examples demonstrate the efficacy of such CP schemes on the control of urban congestion, and the residents' approval of these schemes is a direct outcome of their successful implementation. The CP technique is just one of a variety of approaches used to reduce congestion, and this is something that all four successful situations share in common. The funding of alternate modes of transportation, particularly public transportation, is a further crucial point. According to the findings of Kottenhoff and Brundell Freij (2009), the provision of public transportation might play a very important part in the Comprehensive Plan policy package. Public transportation can aid in reducing the usage of vehicles and encourage mode switching, whereas sole CP schemes will alter the drivers' route and journey time to demonstrate the reduction of traffic during peak-hour windows (Santos, 2005). One of the auxiliary changes to CP to address inequality and improve the policy's acceptability is the redistribution of revenues (Tian, 2015). On the other hand, it is essential that the policies be as straightforward as possible. People's distaste of intricate mechanisms was evident from the failures in Edinburgh and Manchester. People in Singapore and Milan, respectively, are more accepting of the simpler ERP and Area schemes than they are of the previous ALS and Ecopass (Gu et al., 2018; Hensher and Li, 2013).

Public acceptance

Urban congestion pricing methods, despite having a considerable amount of theoretical research, can only be applied in a small number of real-world situations worldwide. Public acceptance is the main barrier to the introduction of CP (Albalate and Bel, 2009; Banister, 2003; Glazer and Niskanen, 2000). Road usage is something that most people take for granted. Naturally, charging for a good that is constantly free is difficult to get people to accept. Cities that failed to implement CP programs include Manchester, New York, Edinburgh, and Hong Kong (Albalate and Bel, 2009; Gu et al., 2018). Even in Stockholm's vote, they disregarded outlying citizens' objections because they rely more on cars to go to urban centers.

However, equity is seen as the cornerstone of acceptance and is of major significance to stakeholders (Perera and Thompson, 2020). (Langmyhr, 1997; Viegas, 2001). People frequently perceive CP as an additional tax on drivers. Additionally, it results in low-income drivers ceding their rights to the roadways to those who earn more money or has more value of time (VOT) . These low-wage drivers would suffer from CP if the funds were not used to upgrade the public transportation system. Low-income drivers and individuals with restricted mobility have more difficult travel constraints and further restrictions on their travel options in the context of out-of-pocket costs (Gu et al., 2018). Therefore, there are distinct discounts for some specific groups in London, Stockholm, and Milan. The designs of CP policies in the situations of Hong Kong, New York, and Edinburg did not give adequate consideration to equitable issues, which became the primary cause of people's criticism (Larson and Sasanuma, 2010; Pretty, 1988; Ryley and Gjersoe, 2006). Therefore, a more appealing and equitable strategy is required.

Tradable mobility credits

Early works

A type of plan based on tradable mobility credits is suggested as a solution to address the most pressing equity issue of CP and win the support of the general people (Fiorello, 2010; Gulipalli et al., 2008; Raux, 2004). The overall idea is straightforward. Users are given a set number of mobility credits to use during a specific time frame. Drivers will be charged credits rather than out-of-pocket money when they enter a charging zone or pass through a charge cordon. Those who use all their credits must purchase from the government or other users.

While classic CP was viewed as a stick, Tian (2015) termed it as a stick-and-carrot mixed method. Drivers with a low value of time (VOT) in this scenario take the initiative to limit their vehicle use and profit by selling their excess credits, while those with higher VOTs are responsible for covering the external costs of congestion. In reality, the concept of mobility credits is not new in the field of congestion reduction. A mixed rationing and price plan was put forth by Daganzo (1995). This plan can be compared to the distribution of mobility quotas without trading. Viegas (2001) considered the quota system using the idea of "mobility rights." Presently, drivers receive unlimited quotas of mobility rights to drive, therefore the free allocation of limited quotas might be viewed as a diminution of the current state of affairs. Early research mostly concentrated on concept formulation, policy design, qualitative analysis, and discussion of the possibility of implementation and responses from stakeholders. Verhoef et al. (1997) presented various different kinds of tradable permit schemes based on ownership, distance, fuel usage, and parking, respectively, to address congestion externalities.

The TMC concept is then put forth with more certainty. Transferable permits, according to Raux (2004), might be a bridging solution to congestion issues. Later, he elaborated on the concept of the transferable driving rights program, under which those residents are given a specific number of driving rights and are free to exchange any unused driving rights with others who require a lot of journeys (Raux, 2007). In parallel, a revenue-neutral credit-based congestion pricing (CBCP) strategy was developed by Kockelman and Kalmanje (2005). Owners of registered vehicles receive a monthly stipend in the form of travel credits.

Unless they run out of credits, they don't have to pay anything, and those who have extra credits can store them away for the following month or trade them in for cash. It was further refined with more specificity through additional work based on expert polls (Gulipalli et al., 2008). Ch'ng (2010) proposed a trading credit system with a two-sided auction market where supply and demand would set the cost of mobility credits. Based on an auction market experiment, he investigated how transactions enable revenues to be returned to drivers who switch to other alternative modes and the realization of the utility equilibrium between sellers and purchasers. The TMC schemes often have the following characteristics: 1) The administration division decides the total number of credits and distributes them to qualified individuals; 2) Credit exchange is permitted: those who travel less can sell their unused credits to those who have used them all; and 3) Similar to congestion pricing plans, the rates for mobility credits may change depending on the time, place, route, or kind of vehicle.

Quantitative studies and development

Although the concept of such a scheme is straightforward, further works require more than intellectual talks. Research began to focus more on quantitative studies in the last ten years. Genoa was used as a case study by Fiorello et al. (2010), who created a system dynamic model of Genoa Mobility Rights to calculate the effect of TMC on individuals in a sequential manner. Yang and Wang (2011) pioneered the quantitative analysis and modeling of the system and introduced a tradable travel credit system. They pretended that there were uniform travelers who could exchange their travel credits in a free and open market without interference from the authorities.

They then looked further into the complex problem of heterogeneous drivers with various VOTs (Wang et al., 2012). The works that come after that add to the circumstance of heterogeneous users. Wu et al. (2012) created a modeling approach to account for the effects of credit distribution on travelers with various income levels and geographic characteristics in order to support a more fair TMC scheme. According to He et al. (2013), the authority must deal not only with individual travelers but also with transportation providers (such as logistic companies and transit agencies). These two categories of consumers will each receive a different number of credits from the differentiated scheme, as well as a different rate. Zhu et al. (2014) developed a method that may decentralize a goal network flow pattern into a user equilibrium link flow pattern under the assumption that travelers have constantly spread VOTs. And in recent years, this discipline has seen an increase in the number of articles published. A new TMC program created by Nie and Yin (2013) offers credits to travelers who skip the peak-hour window or use other alternate modes. Their research suggests that even a very straightforward TMC design can provide notable efficiency. Miralinaghi and Peeta (2016) developed a multi-period TMC scheme in which travelers are permitted to utilize, sell, or transfer credits to subsequent periods. They contend that this plan can keep the price of credits stable. A link-based cyclic tradable credit scheme was put up by Xiao et al. (2019), in which users could be taxed for or given subsidies for the compensating credits. Wang et al. (2020) integrated the TMC scheme with a link capacity enhancement measure and established a bi-objective bi-level model to balance economic development and environmental concerns in terms of sustainable-oriented transportation.

Participants' responses are crucial for transportation system management policy. To investigate travelers' loss aversion behavior for credit collection throughout the route choosing process, Bao et al. (2014) used a disutility function. To assess the impact of the TMC on people's mode of transportation and travel behavior, Xu and Grant-Muller (2016) conducted simulation study in Beijing. In the contexts of credit trading and route selection, Tian et al. (2019) investigated how people interacted with each other and with intelligent virtual agents. Dogterom et al. wrap up a more thorough analysis of the behavioral effects (2017). Inevitably, TMC receives more public support in terms of the question of public acceptance. TMC was established as a workable and competitive alternative by Kockelman and Kalmanje's work in Austin, Texas, in 2005. Similarly, a survey conducted in the UK found that TMC was more well received by the general public than CP, and participants agreed with its fairness (Harwatt et al., 2011).

Current problems

TMC is a novel approach to congestion management, and as of yet, no real-world applications have been discovered. Some problems still call for deeper understanding. The biggest concern among researchers for TMC is the administrative costs. Authorities must work on determining which recipients are eligible, allocating credits, observing use and transactions, etc. As a result, the TMC system will have higher administrative costs than standard CP schemes (Fan and Jiang, 2013; Nie, 2012; Verhoef et al., 1997). Particularly, the transaction cost is a recent issue that should be taken into account but hasn't yet received enough attention. According to He et al. (2013), transaction costs will alter both the pricing and the route that travelers take while reducing the volume of mobility credits traded. According to Zhang et al. (2021), transaction costs can have a detrimental impact on travel utility for those with low VOTs, and they recommended implementing equity constraints in TMC design. TMC is also considered a substitute for CP. Although the redistribution of funds to alternative modes of transportation is generally supported in CP systems, there aren't enough insights in TMC. In free-market schemes, revenues might be collected as a commission charge, whereas in schemes like CBCP, revenues could be collected directly. In reality, the administration department may find it more efficient to redistribute the bonus to drivers and other transportation initiatives via CBCP. Authorities must strike a balance between rewarding drivers with a percentage of the proceeds and funding transportation initiatives, as well as taking administrative costs into account. Another problem is that there is still disagreement among researchers on who should receive credit. Generally speaking, there are two groups that we can divide the objects into: one is a more restricted group that only refers to drivers or automobile owners (Ch'ng, 2010; Kockelman and Kalmanje, 2005; Verhoef, 1997), while the other group comprises all taxpayers or local residents (Fiorello, 2010; Raux, 2007; Viegas, 2001; Yang and Wang, 2011). It is crucial to identify the proper TMC users because they are crucial for quantifying the overall number of credits. The number of credits will have an impact on the trading price and operational costs whether the system uses an auction or free trade market for transactions.

CONCLUSION

This article reviews the successful initiatives in Singapore, London, Stockholm, and Milan beginning with the concept of urban congestion pricing. Enough academic studies and real-world examples have demonstrated that public acceptance is the greatest barrier to the adoption of CP systems and that equity should be the primary consideration. Thus, we evaluate the literature on TMC systems, which were presented as a more equitable congestion management strategy to bypass CP's deficiency.

Even though a lot of conceptual, qualitative, and quantitative research has been done, TMC schemes still don't have any implementation procedures. Compared to conventional CP, the TMC offers more complex administration and operation systems. Future study is advised to make TMC systems more relevant by using the cases of CP as a guide.

Primarily, work on heterogeneous users can be more specifically targeted. According to the input from those CP examples, the delivery sector benefits from easy transportation in urban locations. The reduction in traffic, particularly during peak-hour windows, enables the delivery business to plan their schedule more freely. Urban freight vehicles, nevertheless, are more responsible for urban congestion due to their frequent journeys and larger size. To balance the connection between freight trucks and private vehicles in the context of different users, TMC's future activities may focus more on urban freight delivery. In addition, it is vital to reinvest earnings in the public transportation system or active mobility alternatives. The level of service provided by various modes of transportation should be improved as more drivers switch from driving to other modes of transportation including public transit (metro, commuter rail, bus, etc.) and active modes (cycling, walking, and PMDs). The balance between the bonuses received by individuals and the money invested in projects for alternate transportation can therefore be the subject of future research.

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