CITY CENTRE ROAD USER CHARGING; REAL SCHEMES AND FIELD-BASED EXPERIMENTAL STUDIES: STATE OF ART

Aziza Safour[1] and Charles Egbu

School of Built Environment, University of Salford, Salford M5 4WT, United Kingdom

Recently, road user charging (RUC) is considered a suitable tool for tackling urban traffic and transport problems. All over the world, there are different types of road user charging which have been implemented in order to reduce traffic congestion in the centres of the cities. This paper, firstly, focuses on reviewing existing examples of real RUC schemes which are applied to solve congestion traffic problems, such as in Singapore, Durham, London and Dubai. Other cities have used RUC to obtain revenue for new infrastructure funds; for instance, Bergen, Oslo and Trondheim. This paper also discusses a number of field-based RUC experiments that have been done to study the behavioural response towards road charging policy. The sample size of these experiments ranges from twenty three in the Dublin experiment, to thirty seven in Newcastle experiment and five hundred in the Copenhagen experiment, with continuous experimental periods between two weeks to over one year. The results of the existing RUC schemes and field experiment RUC studies indicated that road users might react or act in response to a RUC in several different ways. For instance, some of them prefer to change their departure time to earlier or later to avoid charges. Others change their mode of travel while some of them preferring to choose new destinations for certain activities. The analysis of real RUC schemes and field-based RUC experiments have concluded that RUC could be a powerful instrument in reducing traffic congestion, in raising revenue and in improving the environment in cities centres.

Keywords: road user charging, traffic congestion, transport.

INTRODUCTION

Road-user charging can be defined as a method of collecting money from road users, which refers to charging for the use of the road (Johansson and Mattsson, 1995). Whittles, (2003) defined road pricing as an asset of ideas that can be applied in urban areas to charge road users particularly when they drive in urban areas. Recently, road user charging (RUC) is considered a suitable tool for tackling urban traffic and transport problems. All over the world, there are different types of road user charging which have been implemented in order to reduce traffic congestion in the centres of the cities. This paper, aims to review the existing examples of real RUC schemes which are applied to solve congestion traffic problems, such as in Singapore, Durham, London and Dubai, other RUC schemes that have applied to obtain revenue for new infrastructure funds; for instance, Bergen, Oslo and Trondheim. Furthermore, the paper focuses on reviewing a number of field-based RUC experimental studies that have been done to study the behavioural responses of road users toward road charging

[1] a.safour@pgr.salford.ac.uk

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policy. This paper represents a review of road charging policy as a part of an ongoing doctoral research that aims to ascertain and document the perceived impacts of road user charging on individual's activity travel patterns in Libyan cities. As far as the researcher is aware, this study is the first that conducting in the Libyan context. The next part involves the main objectives of RUC, the types of RUC and methods of charging.

OBJECTIVES OF TRANSPORT POLICY AND ROAD USER CHARGING

The increasing use of private vehicles in urban areas which have high population density, mixed land use and relatively high income levels have caused major negative externalities such as congestion and pollution. On the other hand, transport policies are considered as valuable to help government and local authorities to solve various transport problems. One of these policies is road user charging (RUC) which is considered as a practical technique uses to solve or reduce traffic congestion and transport problems.

To create charging policy that is effective against congestion, some trips would have to be cancelled, while others would have to adapt their mode of travel, destination, frequency or time of travel. This would mean a change in both, the lifestyle and style of travelling of an individual or the whole household, and this change involves rescheduling activity patterns, in terms of where, when, how, and with whom these activities are scheduled during the day or week, in order to achieve their desired activity participation (Bowman and Ben-Akiva, 2001). The main objectives of road user charging can be summarized in the following points.

- The economic objective that relates to how congested networks could be used by efficient methods that target to rise the revenue for infrastructure investment; and.
- The environment objective which aims to reduce the environmental externalities such as pollution, noise, visual intrusion and accidents, land use development and road safety (Lewis, 1994, Whittles, 2003).

Types of road user charging

Ison, (2004) have classified the options of road user charging according to the method of charging into the following categories.

a. Congestion-based charging: charge the drivers who cause congestion where this charging would differ according to the traffic conditions.

b. Time-based charging: in this type the charge would be according to time spent travelling within the charged area.

c. Distance-based charging: where drivers are charged for the distance travelled in the area of charging.

d. Point-based or cordon-based charging: drivers charged when they pass boundary points of cordon encircling area or screen lines dividing an area.

Methods of road user charging

Methods of road charging are generally classified into two categories.

a. Indirect charges methods: indirect charging methods usually involve fixed charges for car ownership, such as: purchase tax on acquisition, annual vehicle

licence fees, and variable charges for usage, for instance; taxes on tires; spares; oil and fuel, and daily/hourly parking tax (Lewis, 1994).

b. Direct charges methods: direct charging methods comprise monitoring the time and distance of vehicle travel. This type can be subdivided into off and on-vehicle metering, where off-vehicle charging involves manually operated tollgates and on vehicle charging methods require to place an electronic charging instrument in the vehicle (Johansson and Mattsson, 1995).

The following part comprises a review of worldwide RUC schemes and field-based RUC experimental studied.

ROAD USER CHARGING: REAL SCHEMES AND FIELD EXPERIMENTS

Recent years have seen growing interest in RUC as a policy tool to control traffic congestion in urban areas. For many years Singapore scheme which implemented in 1975 was the only example of city centre congestion pricing. These days, there are several examples that have made considerable progress toward RUC policies.

Example of Worldwide RUC Real Schemes

The real cities centres of RUC implementations can be divided according to location, application and method of charging.

City centre point-based or cordon-based congestion charging

Singapore area licence scheme and Singapore electronic road pricing (SERP).

In 1975, Singapore was the earliest city to introduce a city centre congestion pricing scheme based on area licensing. The scheme was targeted to reduce the traffic congestion in the central business district (CBD); and to improve the efficiency of the network system by freeing road space for public transport to be more frequent and faster (Whittles, 2003). After the introduction of the scheme, the traffic entering the centre during the restricted periods decreased by 44%. In contrast, traffic increased by 13% during the hours after peak time. The traffic speed increased to 22% in the centre (Small and Gomez-Ibanez, 1998). In 1998, the Singapore area licence scheme was upgraded to the electronic road pricing (SERP) system. The enforcement system is fully automated using a pre-paid smart card. The road traffic of SERP system was decreased by about 25000 vehicles during the peak hours (from 270,000 to 235,000) with a rise of average road speed by about 20% (Santos, 2005).

London congestion charging scheme (LCCS).

The first proposal of charging policy in London was a licensing scheme within a defined area during peak hours, the plan was proposed by the Council of Greater London during the 1970s. The proposal was predicted that the charges would reduce traffic dramatically and increase peak hour speed by as much as to 40%. Through the 1980s, a new proposal was considered for three concentric cordon rings with the innermost surrounding Central London and the outermost surrounding Inner London. The plan was recommended that the proposed tolls would reduce inbound traffic by as much as to 15% into Inner London and to 25% into Central London (Chow, 2006). In 2003, in London, a single cordon point-based congestion charging scheme was introduced in central area of the city. This scheme aims to reduce the level of traffic in central London, improve the speed of private cars and speed up the improvements in public transport system. The charge scheme has reduced the volume of traffic in the charging zone from 15% to 20% and increased the car speed to about 40% faster than before (Santos and Fraser, 2006).

Durham charging scheme.
In 2002, the city council of Durham applied the first congestion charging road scheme in Britain. The scheme aims to resolve the divergence between vehicles and pedestrians, improve the environment, protect the pedestrian area and to provide safety for all road users in the city centre. The scheme has delivered both environmental and road safety benefits to Durham's city centre, and it has significantly reduced traffic entering the restricted area by 90% and has increased the pedestrian activity by 10 % (Durham City Council, 2004).

Norwegian toll rings (Bergen, Oslo and Trondheim).
The aim of Norwegian toll rings is to raise the revenue of the roads without any changes in traffic volume and departure time. The earliest Norwegian road pricing scheme was in Bergen in 1986 and the toll system was proposed to finance the new constructed roads. In 1990, the second road pricing scheme was introduced in Oslo which is the nation's capital. The charge was made for every vehicle entering the cordon placed around the city and there is no toll for traffic going out of the city centre. The last urban road pricing scheme was implemented in Trondheim in 1991. The impact of charging scheme has reduced vehicles crossing the charging zones by no more 5% to10 % and this impact was expected because the charging fees were just small part from the people's daily travel costs (Lewis, 1994 and Small, 1997).

b. City centre area-wide congestion charging
Salik, Dubai road toll System.
SALIK is a congestion charging scheme started on July 2007 in Dubai, the United Arab Emirates. The scheme aims to reduce congestion and improve traffic management on Shaikh Zayed Road, which is one of the most crowded highways in the city (Salik, 2007). The RTA (Roads and Transport Authority) of Dubai expects that the tolling system will reduce traffic by around 25%.

Field-based RUC experimental studies
As mentioned previously, road-user charging is considered a suitable tool for tackling urban traffic and transport problems, however, it's impact on the travel pattern of individuals is largely un-investigated (Keuleers *et al.*, 2006). In the next part the researcher focuses on number of field-based RUC experimental studies.

The MobilPASS field trial in Stuttgart Germany
Hug *et al.* (1997) have described the MobilPASS field-trial in the southern part of Stuttgart which was the first field-trial to test the impact of road user charging on the travel patterns of road users. The field-trial conducted from February 1994 to March 1995 involved 400 drivers using a number of face-to face interviews/ mail-back questionnaires. Moreover, the participants were asked to make a record for their travel in a logbook, beginning three months before and ending one month after. To achieve realistic results, the participants were asked to use a MobilPASS smart card to pay the toll. The results of the study indicate that the percentage of car trips that moved to cheaper periods was up to12.5%. Nearly one-third of respondents have shifted their destinations elsewhere.

Newcastle trial: investigating driver's responses to road user charging using GPS
Thorpe and Hill (2003) illustrate a field-based trial using Global Positioning System (GPS) was conducted between May and September 1997. This study tends to focus on assessing driver's willingness to pay. In this trial two methods of road pricing were applied; point-based charging and distance-based charging. Thirty volunteers took part in the trials. In the field-trial the participants were allocated a real travel

budget within the range of £13 to £28 for the two-week trial. The participants travel data were recorded by using two methods. An on-board car unit which recorded the trip data automatically and a travel diary recorded by the participants during the two weeks of the trial. The results of the field-trial indicated that more than half (51%) of the drivers for the inbound trips preferred to pay the prevailing charge and travel at the preferred time. The percentage of respondents who avoided paying the charge by changing their route was 44%, whereas, only 5% of the trips were re-timed.

Leicester, EUROTOLL project
In Leicester, as part of EUROTOLL project (European Project for Toll Effects and Pricing Strategies), Francsics and Ingrey (2000) have examined the route choice and mode choice for 100 drivers. The charge system was using point-based charging and the participants were allocated a real budget to be used for the toll incurred. The results suggested that RUC has clear effects on car usage and shown that it is possible to use RUC as an effective method to reduce the using of cars.

Hong Kong's electronic road pricing trial
Hong Kong government has planned a complex system of road pricing using electronic charging and video enforcement (scanning via AVI, automatic vehicle identification) at a number of toll locations. The proposal was targeted to improve the efficiency of the network, free road space and accessibility and improve the economic growth. The scheme included three different cordons with different charges. The predicted results mentioned that the peak period traffic had declined by around 20% to 24 % and the total daily car trips would be decreased by around 9% to 13% (Small, 1997).

Distance and time-based road pricing trail in Dublin
In Dublin, Ireland, O'Mahony *et al.*, (2000) estimated the potential user response to a hypothetical of two types of road pricing policies; distance-based and time-based charging. The sample included twenty three volunteers chosen randomly to contribute to this trial. In the field trial, a RUC scheme was applied on weekdays over a period of six weeks. The trial was conducted with the commuters, where the focus of the trial was on the peak period work trips within Greater Dublin. The results of the trial indicated that a significant reduction in the use of cars can be obtained where a 22% reduction occurred in trips during the peak period.

The AKTA road pricing experiment in Copenhagen
In the Danish AKTA experiment of Copenhagen, Denmark, Nielsen (2004) studied the driver's responses to RUC scheme. In this study 500 cars equipped with GPS-based devices were used through the three main parts of the experiment. In the first part, the normal travel patterns for the participants were estimated during the control period over 8-12 weeks. In the second part, the pricing scheme was applied for another period over 8-12 weeks by using a cordon-based system. The third part included a questionnaire survey that asked a 300 of road users. The results of the experiment concluded that the road pricing scheme has an effect on the travel behaviour of participants and the GPS-data offered very good knowledge of travel times and congestion in the network.

The second trial in Newcastle: behavioural change in activity-travel patterns in response to road user charging
Chow, (2006) has studied the impact of road-user charging on household mobility and activity participation patterns in the city of Newcastle upon Tyne, UK. This study used the data of a real field experiment that was conducted through the period of 25th

February to the 4th March 2002 with a total of 50 households being recruited at city-centre car-parks and 37 households returned their travel-activity diaries. During the experiment the household participants was allocated £25 per week as a budget to be paid for the toll incurred. All household members aged 16 years and above were asked to record a seven days activity travel diary, before and after the introducing of RUC. The result of this experiment suggested that the scheme was very effective in reducing the number of contributor's cars in the charged area at the peak period to 60%.

Lastly, comparisons studies of real schemes and field-based experiments of road user charging in the urban areas can be shown in Table 1 and Table 2.

DISCUSSION

Singapore and London schemes provided best examples of road user charging that can be applied in CBD area of the cities where the main targets of these schemes are reducing traffic congestion and improving the environment extent of the urban areas. The outcome of these schemes represented that these schemes have been successful in the solving transport problems such as congestion and environment pollution. Furthermore, theses schemes used cordon or point-based charging as a type of charging which is the simplest in term of operation, enforcement and technology readiness that can be suitable for the research study area. They also used the peak period toll hours that could be the effectiveness time that can be used for charging scheme in the case study area where traffic congestion reach the high rate at the morning peak period. Considering the case study area circumstances, the peak period toll hours will be helpful to use, where during the peak periods hours, the majority of streets of Benghazi city centre are congested with cars up to the limit of their capacity.

The review of various field-based charging experimental studies has been done using number of studies that investigated road user's responses to road user charging. Hug *et al.*,(1997), Thorpe and Hill (2003), Francsics (1998), O'Mahony *et al.*, (2000), Nielsen (2004) and Chow (2006) are the most studies that examined road users responses and provided detailed information on how users could adopt their travel patterns over time in response to road user charging. The common positive aspect of these field experiments is the use of real budget to achieve more realistic decision from the participants. This process of using real budget helps the researcher to enhance the validity of the experiment in the case study area. Other worthy points are the use of peak period toll hours which are the effectiveness time that can be used for charging, multi-days data by recording activity travel data for two periods before and after introducing of road user charging. Thorpe and Hill (2003), Francsics (1998), Nielsen (2004) and Chow (2006) have used point-based or cordon-based charging as the type of charging for the field experiment. The majority of these studies focused on the investigating of changes in individual's activity travel patterns. However, Chow (2006) has examined user's responses by focussing on household activity travel patterns using multiple days (7days before and 7days after). In the doctoral research, the researcher follows the examples stated above by using a real field-based experiment. A pre-paid experiment budget, cordon-based charging, morning peak period toll hours and multiple activity travel data (7days before and 7days after) are used to ascertain and document the perceived impacts of road user charging on individuals activity travel patterns in Libya cities. The sample comprises of 120 participants of road users for the real experiment and 60 participants of road users for another sample that uses as a control group. The results of study could be of benefit to transport policy makers in Libya.

CONCLUSION

This paper focuses on reviewing the main objectives of road-user charging policy that can be summarized in the following; the economic objective (in terms of raising the revenue for transport sector) and environment objective (in terms of reducing the pollution and improving the roads conditions). The second subject reviewed was road user charging types that involve congestion-based charging; time-based charging; distance-based charging and point-based or cordon charging. Methods of charging that classified into two types; indirect charges and direct charges. Moreover, the review involves examples of worldwide implementation of road user charging and field-based RUC experiments that studied road user's responses toward road charging policy. The analysis of real RUC schemes and field-based RUC experiments have concluded that RUC could be an effective instrument in reducing traffic congestion, in raising revenue and in improving the environment in cities centres. According to the previous studies, the key features of RUC experiment have determined for the field-based study in Libya, and the study results could be of benefit to transport policy makers in Libya.

Table 1: Comparison study of seven real cities centres road user charging schemes

City centres road charging Locations ► / City centres road charging features ▼	Singapore	Bergen	Oslo	Trondheim	Durham	London	Dubai	Total
Objectives								
- Reduce the traffic congestion	✓				✓	✓	✓	**4**
- Raise the revenue		✓	✓	✓			✓	**4**
- Improve the network efficiency	✓							**1**
- Improve the private car speed						✓		**1**
- Protect the pedestrian in city centre					✓			**1**
- Speed up public transport improvements	✓					✓		**1**
Type of Scheme								
- Congestion-based charging								**0**
- Time-based charging								**0**
- Distance-based charging								**0**
- Point-based or cordon charging	✓	✓	✓	✓		✓		**5**
- Area-based charging		✓	✓	✓	✓		✓	**5**
Charging technique								
- Electronic payment system	✓		✓	✓		✓	✓	**5**
- Manual payment system		✓			✓			**2**
Toll hours								
- All hours & all days			✓				✓	**2**
- Weekdays; long period				✓		✓		**2**
- Weekdays; two peak periods								**0**
- Weekdays & weekend; long period		✓			✓			**2**
- Weekdays& weekend two peak periods	✓							**1**
Type of Charging								
- Per-entry charge	✓	✓		✓	✓			**4**
- Per-day charge			✓			✓	✓	**3**

Table 2: Comparison Study of eleven field-based road user charging experiments

Field-based Road User Charging Experiments Locations ► Key Features ▼	Trondheim	London	Stuttgart	Bristol	Newcastle 1	Leeds	Leicester	Hong Kong	Dublin	Newcastle 2	Copenhagen	Total
Type of Survey												
- Stated Preference	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	**11**
- Stated Adaptation			✓							✓		**2**
- Stated Tolerance												**0**
- Stated Prospect								✓				**1**
Survey methods												
- Mail-out &mail-back	✓		✓			✓						**3**
- Face-Face questionnaire			✓		✓							**2**
- Site interviews		✓		✓				✓				**3**
- Real-field experiment			✓		✓		✓		✓	✓	✓	**6**
- Pre-paid experiment budget			✓		✓		✓		✓	✓		**5**
Type of Hypothetical Scheme												
- Area-based charging	✓											**1**
- Time-based charging			✓						✓			**2**
- Distance-based charging			✓		✓				✓			**3**
- Point-based or cordon charging	✓				✓		✓			✓	✓	**5**
- Without hypothetical Scheme		✓		✓		✓		✓				**4**
Sample Size												
- Less than 50					✓				✓	✓		**3**
- Around 100							✓					**1**
- Around 500	✓		✓	✓				✓			✓	**5**
- More than 1000		✓				✓						**2**
Toll Hours												
- All hours & all days			✓								✓	**2**
- Weekdays; peak period									✓	✓		**2**
- Weekdays; two peak periods					✓							**1**
- Without toll	✓	✓		✓		✓	✓	✓				**6**
Type of Data												
- One-day activity travel diary												**0**
- Multi-days data activity diary			✓							✓		**2**
- Multi-days data without diary					✓		✓		✓		✓	**4**
- Without diary or multi-days data	✓	✓		✓		✓		✓				**5**
Investigation Aspects												
- Ranges of user's response	✓			✓	✓							**3**
- Time of departure		✓										**1**
- Route choices			✓				✓				✓	**3**
- Purpose of trip			✓						✓			**2**
- Mode choice			✓				✓					**2**
- Time travelled			✓			✓			✓		✓	**4**
- Car usage						✓		✓	✓			**3**
- Distance travelled									✓			**1**
- Car speed											✓	**1**
- Drivers willingness to pay					✓							**1**
- Car ownership								✓				**1**
- Toll amount									✓			**1**
-Households' activity patterns										✓		**1**

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