Road pricing in a polycentric urban region: analysing a pilot project in Belgium

Abstract

In order to cope with growing car use and congestion, academics often suggest road pricing as a way to reduce car use and internalise external costs (such as congestion and air pollution). However, implementations of road pricing schemes are rather limited and mainly focus on large cities (i.e., cordon charges). Recently, the three regional governments of Belgium − a highly urbanised and polycentric country – have commissioned a pilot project of an area-wide, time- and location-differentiated road pricing scheme, hence differentiating charges according to the time of the day and the type of road used. Results of this project indicate that kilometres travelled by car mainly reduce in urban areas, while car use on motorways only reduces to a limited degree. Furthermore, results indicate that urban residents adapt their travel behaviour more than suburban and rural residents, probably because urban dwellers have more alternatives to travel than driving personal cars only, especially on the short run. In this paper, we will analyse the preliminary outcomes of the conducted pilot project, look into the limitations of this project and suggest an alternative road pricing scheme.

Keywords

Travel behaviour; Road pricing; Belgium; Residential location; Land use

1. Introduction

Although recent studies suggest that car use is ceasing to grow in the developed economies ('peak car use') (Metz, 2013; Newman and Kenworthy, 2011), most western countries have experienced a rapid increase of motor-vehicle-related inconveniences in recent decades, particularly in the form of congestion and associated environmental nuisance, urban liveability problems and hampered economic growth. The high car use can be partly explained by relatively low travel costs. Car users, for instance, only pay for the internal costs of their travel (e.g., purchase of the car, fuel, insurance), but do not pay the costs they cause to third parties. These external costs − such as congestion, air and noise pollution − are paid by all tax payers and not only by those people who cause them (especially car users). Therefore, road pricing policies are being considered and even implemented in various urbanised areas around the world (e.g., Eliasson et al., 2009; Santos, 2005; Tillema et al., 2010a, 2010b, Vonk Noordegraaf et al., 2014). Doing so, external travel-related costs such as time loss and air pollution could be internalised (e.g., Rouwendal and Verhoef, 2006). Such an application of the user-pays or polluter-pays principle is supposed to result in drivers paying full delay and environmental costs, making people more conscious of their travel behaviour (consequences). In the short run, road pricing might lead to changes in travel mode choice and destination choice, and in departure time and route choice in case of a time- and location-differentiated road pricing scheme. Although often neglected by policy makers, road pricing can also have effects on the long run. In the longer term, car ownership may be affected while people may become encouraged to change their residential location or look for a job closer to home (Arentze and Timmermans, 2007; Banister, 2002; Eliasson and Mattsson, 2001; Tillema et al., 2010a, 2010b; van Ommeren et al., 1999).

Today, toll roads, toll tunnels and toll bridges are abundantly present around the world, while in a number of cities (London, Singapore and Stockholm, to name a few) a cordon toll for entering the city centre has been implemented (Börjesson et al., 2012; Goh, 2002; Leape, 2006; Santos, 2005). Road pricing can also take the form of 'value pricing' in which travellers can choose between a free but congested roadway and a priced roadway. High-occupancy toll (HOT) lanes for instance − mainly present in American urban areas − offer an uncongested roadway to people who are willing to pay a time-varying toll (or ride in carpools) on an otherwise free and congested road (Brownstone and Small, 2005; Dahlgren, 2002; Small and Yan, 2001; Sullivan, 2002). People attaching a lot of value to reducing travel time (i.e., people having a high value of time (VOT); mostly related with high incomes) might be more inclined to pay for an uncongested roadway compared to others. Although some regions experimented with VOT-estimates for travellers in regions where road pricing is considered (e.g., the Capital Mega-region, US (Mishra et al., 2014)), or with a charge per kilometre travelled (for instance in the state of Oregon, US (McMullen et al., 2010)), a region-wide, time- and location-differentiated kilometre charge scheme − as is proposed in Belgium − has never been applied before. Although this may in significant part be due to the complexity of such as system (Bradley and Kenworthy, 2012; Ubbels, 2006), it is worth mentioning that in the neighbouring Netherlands, a comprehensive road pricing project has been prepared for years, before being cancelled in 2012 after a lack of public support was revealed (http://www.kilometerheffingnederland.com).

Previous examples indicate that road pricing – and cordon charge in particular − can affect people's travel behaviour. In 1998, Singapore replaced an area licensing scheme – already restricting traffic flows in Singapore to a certain extent between 1975 and 1998 − by a time-differentiated electronic road pricing system to track vehicles entering Singapore's central area. This system uses on-board units, smart cards and overhead gantries to detect incoming vehicles. After the introduction in April 1998, a significant drop of approximately 15% (Olszewski and Xie, 2005; santos, 2005) to 24% (Seik, 2000) was observed in the daily traffic flows in the central area. Since traffic volumes dropped below the expected level, the rates were reduced by 20% in November 1998. However, traffic flows only increased to a limited extent compared to traffic flows in the period April 1998 – October 1998. In general, the road pricing experience in Singapore turns out to be an effective method of controlling congestion, as average travel speeds in the restricted zone improved from approximately 30 - 35 km/h to 40 - 45 km/h (Goh, 2002; Olszewski and Xie, 2005; Santos, 2005; Seik, 2000). In 2003, London imposed a £5 daily charge (increased to £8 in July 2005) for entering the congestion charging zone between 7:00am and 6:30pm, excluding weekends and public holidays. Charges have to be paid in advance, for instance through retail outlets and payment by Internet. Automatic number plate recognition technology at every entry point and in mobile units is used for enforcement. The traffic flow of cars, trucks and vans coming into central London dropped approximately 18% (Santos, 2005; Santos and Fraser, 2006; Santos et al., 2008) to 27% (Leape, 2006) while inbound car traffic reduced with 33% (Leape, 2006). Around half of these trips are being replaced by public transport trips, while people also avoid the charging zone, travel by taxi or bicycle or shift their trip outside charging hours. As a result, average travel speeds in the charging zone increased from 14.3 km/h to 16.7 km/h (Leape, 2006; Santos, 2005; Santos and Fraser, 2006; Santos et al., 2008). In Stockholm, a time-differentiated cordon charge – permanently introduced in 2007 – reduced the number of passages across the cordon significantly. Commuting trips by car reduced by 24%, mostly in favour of public transport trips. Non-mandatory trips reduced with 22%, mostly due to changes in destination choice and decreasing trip frequencies. Finally, commercial traffic (freight traffic, deliveries, business trips, etc.) decreased by 15%. These traffic reductions resulted in substantial decreases in congestion and travel time (variability) (Börjesson et al., 2012; Eliasson, 2008). To the best of our knowledge, favourable outcomes (i.e., reductions in kilometres travelled by car and improved travel times) from other types of road pricing (e.g., charge per kilometre travelled) are not available.

In this paper we will analyse preliminary results from an area-wide, time- and location-differentiated road pricing scheme in Belgium which was conducted from January till April 2014. The remainder of this paper is organised as follows. In Section 2 we give an overview of the Belgian context regarding the land use pattern and general daily travel patterns and give background information on the road pricing pilot project. Primary results of this project are provided and examined in Section 3, while Section 4 discusses the main limitations of the project. In Section 5 we analyse possible alternatives for the applied road pricing scheme. Finally, the conclusion is provided in Section 6.

2. The Belgian road pricing project

2.1 The Belgian context

As in other prosperous regions and countries in the world, car use in Belgium has rapidly increased throughout the post-war period, despite a slight ripple in the growth curve at the time of the oil crisis. In 2014, the yearly amount of vehicle kilometres travelled by car had tripled since 1970, doubled since 1980 and increased by 50% since 1990. However, from 2007 the car use growth rate in Belgium slows down. Today, car use per capita seems to be stabilising, an observation that supports peak car use hypotheses (http://www.statbel.fgov.be). However, some regional differences are still observable. In Flanders (i.e., the northern region of Belgium) car use is still slightly increasing, while in Wallonia (i.e., the southern region) car use seems to stabilise. Interestingly, in the Brussels capital region, which is the largest and fastest growing urban area in Belgium, car use is actually decreasing, even in absolute terms (http://www.statbel.fgov.be). Despite these flattening growth curves, in Belgium, the private motor vehicle is by far the most used travel mode (i.e., 65 % of all the trips in Belgium are car trips), especially − but not exclusively − in non-urban areas (http://www.beldam.be). Congestion and significant travel time losses are the obvious consequences of such an important rate of car dependency, which is mainly manifest near and in the cities of Brussels and Antwerp. However, inter-urban congestion is also present. In Belgium, the ratio of average free flow speed is low and the average delay per kilometre is high in comparison with other countries in Europe (European Commission, 2012). Especially in Flanders, which is the home region of many employees working in Brussels and where the logistics industry is an important economic actor, time losses due to congestion are considered a threat to the growth of the economy. In Brussels, policy objectives aim at reducing vehicle kilometres travelled within the capital region, in the light of making the city more attractive as a living environment. Finally, Wallonia is the least populated region where congestion levels − and other undesired car use externalities − are mostly acceptable. As a result, this region would probably benefit less from a road pricing regime than Flanders and Brussels.

The high car use in Belgium is related with the Belgian land use pattern. Improvements in transport technology since the end of the nineteenth century – reducing travel costs − in combination with limited spatial planning regulations have resulted in urban sprawl. During the Industrial Revolution, Belgium constructed (starting in 1835) the most densified network of trams and trains of all Industrial countries. In combination with cheap public transport passes (since 1869) this enabled labourers to work in the city but live on the countryside. This resulted in a first wave of decentralisation; cities spread outwards generating sub-centres around public transport nodes (De Block and Polasky, 2011;

De Decker, 2011; De Vos, 2015; De Vos and Witlox, 2013). After the Second World War, urban sprawl accelerated even further. The car, first produced before the Second World War, becomes the dominant travel mode after the war. As the car made it easier to reside almost everywhere on the countryside − even in places which were difficult to access by train − it became the transport mode that shapes the land. Suburban, low-density neighbourhoods with good car accessibility emerged scattered around Belgium. People were no longer forced to live either near their place of employment or a public transport stop to transport them there (e.g., De Decker, 2011; De Vos and Witlox, 2013).

Spatial planning regulations did not hinder the geographical distribution of facilities. The limited amount of spatial plans (especially the so-called 'regional plans' in the 1970s) did not cluster destinations (e.g., residential area, industrial area) in urban areas but scattered them over large parts of the Belgian territory. As a result, Belgium has evolved in a polycentric region where the border between city and countryside is hard to draw (Figure 1). Only 12% of the Belgian population lives in a large city (i.e., cities with more than 200.000 inhabitants: Brussels, Antwerp, Ghent, Liège or Charleroi) and 18% in the agglomerations of these large cities (IGU, 2012). The Belgian population is consequently not concentrated in compact cities but is scattered across Belgium. As a result, the Belgian road network is very dense and widespread[1]. Since a large share of Belgian citizens does not live in a large or regional city, a high car dependency has developed as destinations are often outside walking and cycling distance and public transport services are limited in suburban and rural neighbourhoods. As a result, 65% of all trips in Belgium are covered by car (Beldam, 2010).

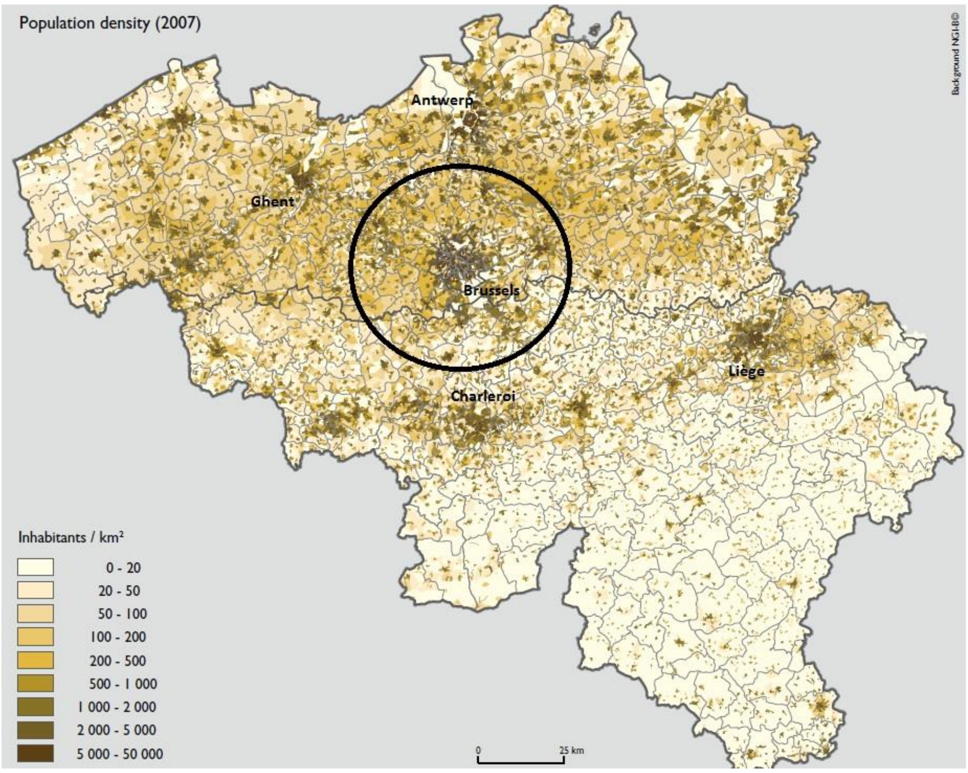

Figure 1. Population density in Belgium (Source: IGU, 2012); commuting area around Brussels indicated by black line (see Section 2.2).

[1] More than 5% of the Belgian land area is covered by road (Nicodème et al., 2011)

2.2 The road pricing pilot project

Although having different objectives – ranging from improving urban liveability (especially in Brussels) to reducing travel time losses (especially in Flanders), the three regional governments in Belgium (i.e., Brussels, Flanders and Wallonia) have decided to join forces and endeavour a road pricing pilot project. Therefore, they assigned a consortium of companies to perform this project[2]. A possible permanent implementation of kilometre charging (resulting from positive results from this project) is meant to replace the current fixed car ownership tax, resulting in vehicle taxation in much closer relation with the actual costs caused by car use. Results of this pilot project should detect travel behaviour changes (e.g., changes in kilometres travelled by car, departure time and route choice) of participants, which would help policy makers to decide whether an actual implementation of road pricing would actually reduce congestion, i.e., the main goal of a potential road pricing scheme. Although the pilot project is intended to analyse potential implementation of road pricing nationwide, the pilot project was conducted in the commuting area around Brussels (i.e., GEN area), containing the city of Brussels and smaller cities such as Leuven, Aalst, and Mechelen − situated in Flanders − and Wavre and Waterloo − situated in Wallonia − within a radius of approximately 30 kilometres around Brussels (see Figure 2). The outcome of the project, however, is not politically binding; favourable outcomes will not necessarily result in an actual implementation of road pricing (nationwide). So far, no decision on the actual implementation of road pricing has been taken by the three governments. Although it is not certain when and if road pricing for cars will be implemented, it has to be noted that trucks (of more than 3.5 ton) are – since April 2016 – actually charged for using the major roads (highways and primary roads) in Belgium; currently overshadowing the road pricing project for cars to a certain extent (http://www.viapass.be).

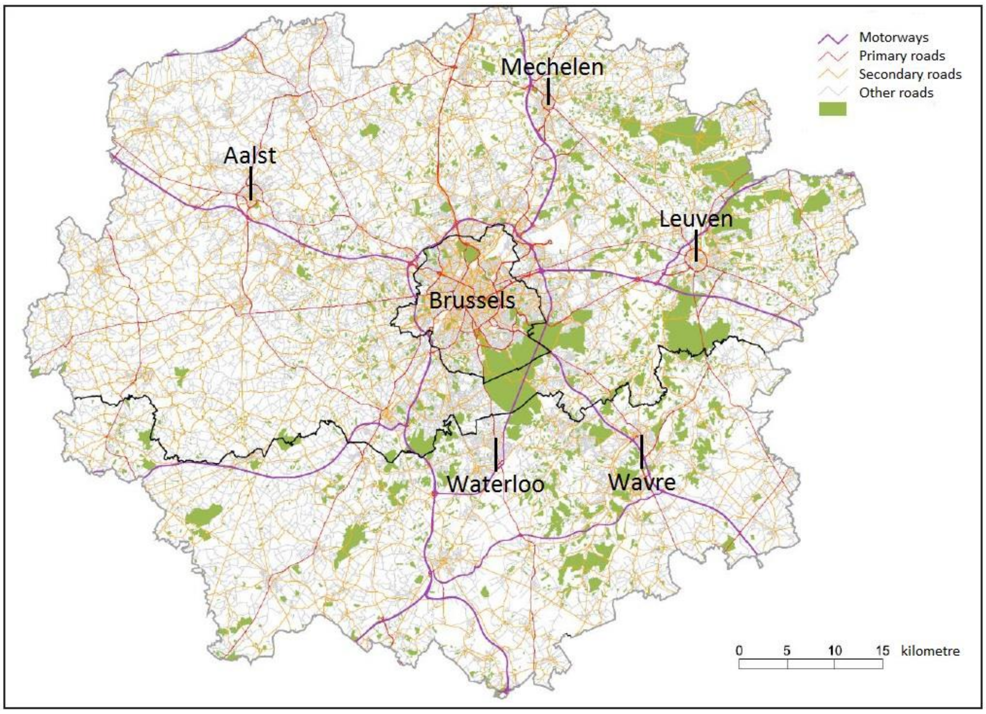

Figure 2. Commuting area around Brussels

[2] This consortium (referred to as 'MOVEIT') comprises the following companies: PwC Belgium, Vito, Magicview Connected Products, GfK Belgium and Touring.

This project can be subdivided into three periods, i.e., (i) sample recruitment, (ii) pre-treatment period, and (iii) the road pricing period. In a first stage, inhabitants of the commuting area around Brussels were randomly contacted by telephone. In order to reduce the number of biased respondents, voluntary participation was not allowed. Furthermore, access to a car was a condition to participate. As a result, urban residents – in particular residents from Brussels – are underrepresented as they often do not possess a car. In total, more than 48,800 individuals were contacted of which approximately 1,715 indicated that they would participate in the project (response rate: 3.5%). 1,187 individuals eventually accepted the participating agreement on the website, of which 820 installed an on-board unit − monitoring the location of the car − in their personal vehicle (lowering the response rate from 3.5% to respectively 2.5% and 1.7%). The relatively low response rate can be partly explained by the high respondents' burden, due to a relatively long engagement of 12 weeks (4 weeks of pre-treatment and 8 weeks of road pricing) including trip monitoring and filling in surveys. Besides urban residents, low-income groups are also underrepresented. Other socio-demographic variables, including age and gender, are comparable with the total population of the area (http://www.viapass.be). Although the low response rate and underrepresentation of certain population groups do not allow a descriptive analysis of the total population, the sample size does allow analytical representation of relationships among multiple variables (Groves, 1989).

During the pre-treatment period of four weeks (mid-January until mid-February 2014), participants' regular travel behaviour was monitored using the on-board unit. This unit provides detailed information on the amount of kilometres travelled by car according to the time of the day and the type of road being used. This information could not be provided (to the same level of detail) by stated preference data gathered from a classical survey. Based on the pre-treatment travel patterns, a virtual travel budget was measured in analogy with road prices which will come into force during the subsequent road pricing period. During the road pricing period (executed during eight weeks, from mid-February until mid-April 2014) participants were charged per kilometre travelled on the selected roads. The applied charging scheme was differentiated according to time and location (Tables 1 and 2). During peak hours (07:00 - 09:00 and 16:00 - 18:00) and within urban areas (of Brussels, Aalst, Leuven, Mechelen, Waterloo and Wavre)[3] participating car drivers were charged 0.09€ per kilometre. On motorways[4], participating car drivers were charged 0.05€ per kilometre, while the use of remaining roads costs 0.065€ per kilometre. Outside peak hours, charges were divided by two; driving your car at night (between 22:00 and 05:00) was entirely free of charge. Rate levels were based on the external costs of car use (i.e., cost of congestion and environmental pollution), resulting in a difference based on the time of the day and the location of the roads. Charges are consequently not based on maximising profit, which might be the case in some public-private partnership tolling schemes (Rouhani et al., 2015). In order to maximise comprehensibility for car users, a limited amount of rates were used (in contrast to 'dynamic pricing' where charges vary in

[3] The urban area of Brussels contains the area within the ringroad R0 and the border of the Brussels Capitol Region in the south. The urban area of Aalst contains the area within the ring road R41 and regional roads N45 and N9. The urban area of Mechelen contains the area within the ring road R12. The urban area of Waterloo contains the municipality of Waterloo and the urban area of Wavre is defined by the motorway E411, regional road N4 and local roads Avenue des Mésanges, rue de l'Ermitage and Rue Provinciale.

[4] Roads designed for high-speed, free-flow vehicular traffic, with no traffic signals, ad-grade intersections or property access and a barrier between opposing direction of travel.

real time according to existing congestion levels) and off-peak charges were cut in half. Although a lot of road pricing schemes are differentiated according to time as congestion is concentrated in peak hours (see, for instance, Coria et al., 2015), spatially variable tolling is a lot less implemented. However, a spatially variable charge can significantly improve travel time (Rouhani and Niemeier, 2014). Although traffic flows and air pollution are subject to seasonal variation (Coria et al., 2015), no seasonal differentiations in the charges were used (partly due to the relatively short project period).

Table 1. Charge per kilometre travelled (in €) per type of road (Source: Viapass, 2014).

	Peak hour	**Off-peak hour**	**Rest of the day**
Urban roads	0.09	0.045	0
Motorways	0.05	0.025	0
Other roads	0.065	0.0325	0

Table 2. Allocation of peak and off-peak hours during the time of the day (Source: Viapass: 2014).

Time of the day	**weekdays**	**Weekends and public holidays**
05:00 - 07:00	Off-peak hour	Off-peak hour
07:00 - 09:00	Peak hour	
09:00 - 16:00	Off-peak hour	
16:00 - 18:00	Peak hour	
18:00 - 22:00	Off-peak hour	
22:00 - 05:00	Rest of the day	Rest of the day

During the road pricing period, participants could see, on the on-board unit and on a website, the amount of money they already spent on road pricing. At the end of the road pricing period, the virtual travel budget (based on travel behaviour during the pre-treatment period) was compared with the amount of money people spent on road pricing during the road pricing period. In the case the virtual travel budget was higher than the sum of the road charges (i.e., when participants adapted their travel behaviour in a positive way by, for instance, travelling less kilometres by car or using the car less during peak hours), participants were paid the difference in money. In the case participants exceeded their virtual budget (e.g., when participants travelled more kilometres by car or used the car more during peak hours) they did not have to pay extra as they voluntarily participated in the project. This could result, however, in an underestimation of the effect of road pricing as participants will no longer be financially stimulated to reduce car use (or change their departure time or route) once they reached the budget level (also see Section 4). Due to the relatively high charges for driving within cities, the proposed kilometre charge scheme can be seen as a combination of an urban cordon charge and a more traditional road toll or charge per kilometre travelled on motorways and non-urban roads. Interestingly, in contrast with common parking pricing policies, no tariff distinction is made between residents of urban cores and residents of suburban or rural areas.

3. Results of the pilot project

3.1 Kilometres travelled by car

Preliminary results of the pilot project indicate that participants adapted their travel behaviour to a certain degree. The amount of kilometres travelled by car reduced on average by 5.6% within the charging zone (i.e., the commuting area around Brussels). However, differences according to (i) the classification of the road, (ii) the time of the day, and (iii) the participants' residential location occur. On motorways, the average reduction of kilometres travelled is 4.2% while this is 7.6% for urban roads and 5.8% for other roads. These differences can be partly explained by variations in road pricing according to the type of road. Surprisingly, the reduction in kilometres travelled is smaller during peak hours compared to off-peak hours (respectively from 58.3km to 56.1km and from 148.7km to 140.2km travelled per week in the Brussels' commuting area), although charges are double as high during peak hours (Table 3). It seems that travel behaviour is easier to adapt for non-commute trips, which are often made outside peak hours. Differences in travelled kilometres according to time of the day seem to be especially present on motorways, where there is no reduction in kilometres travelled during peak hours, but 4.8% during off-peak-hours. This is probably because motorways are used more often for commute trips compared to other roads. Finally, we also see a substantial reduction in kilometres travelled at night (22:00 - 05:00). This is rather surprising as this is the period where travelling is set free of charges. Kilometres travelled at night, however, only account for a marginal share (i.e. 6.3%) of the total distance covered. Outside the charging zone, average kilometres travelled by car increased by 4.3% (during peak hours even by 9.1%), indicating that participants have tried to avoid the charging zone to a certain extent.

Table 3. Change in kilometres travelled by car in the charging zone between the pre-treatment period and road pricing period (Source: Viapass, 2014).

	Peak hours (26.8% of the covered distance)	**Off-peak hours** (66.9% of the covered distance)	**Rest of day** (6.3% of the covered distance)	**Total**
Urban roads (13.5% of the covered distance)	-6.7%	-7.2%	-11.1%	-7.6%
Motorways (25.8% of the covered distance)	0.0%	-4.8%	-10.1%	-4.2%
Other roads (60.7% of the covered distance)	-4.4%	-5.3%	-11.0%	-5.8%
Total	-3.6%	-5.5%	-10.8%	-5.6%

Participants' residential location[5] also affects kilometres travelled by car. In comparison with the pre-treatment period, urban residents travel on average 9.3% less kilometres by car during the road pricing period (from 244.6 km to 222.4 km per week (both inside and outside the charging zone)), while this is only 1.4% for participants living outside urban areas (from 342.3 km to 337.6 km per week (both inside and outside the charging zone)). In most cases, urban residents have – especially on the short run − more opportunities to reduce distance travelled by car as they have more options regarding mode choice and destination choice.

[5] Participants were subdivided into two groups: urbanites (living in urban neighbourhoods) and non-urbanites (living in suburban and rural neighbourhoods). This subdivision is based on density (i.e., population density) and diversity (i.e., the number of amenities in a neighbourhood) (for more information see: http://www.cim.be)

3.2 Travel costs

As the proposed road pricing regime involves a charge per kilometre travelled, participants can adapt their travel behaviour in order to minimise this charge. However, they might also prefer to pay the charges and enjoy free-flow travel[6]. Based on their travel patterns in the period before road pricing (i.e., pre-treatment period), participants were given a virtual travel budget which they could use during the road pricing period. 31% of the participants used less than 60% of their virtual budget, indicating that they dramatically changed their travel behaviour in order to reduce travel costs. 28% and 25% of the participants used respectively 60 to 80% and 80 to 100% of their virtual budget. 16% of the participants spend more than 100% of their virtual budget, indicating that the road pricing had no positive effect on their travel behaviour (Figure 3).

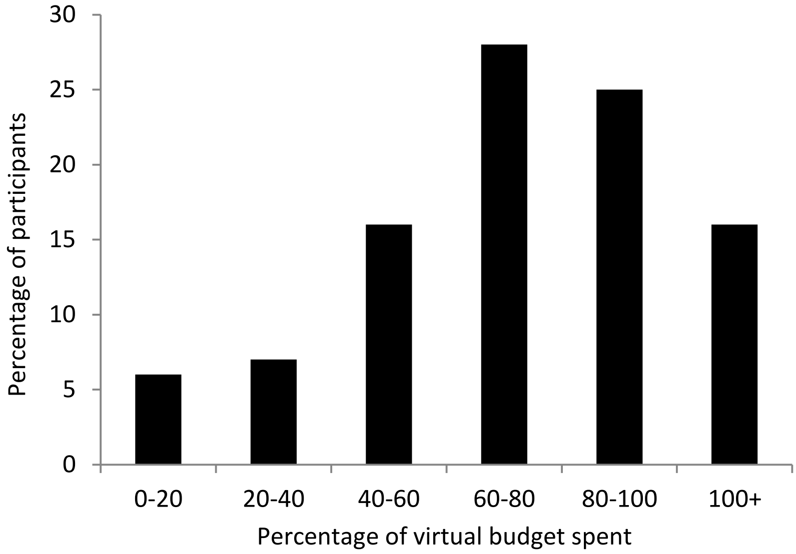

Figure 3. Percentage of virtual budget spent during road pricing period (Source: Viapass, 2014)

There are, however, big differences between participants living in urban neighbourhoods and participants living outside urban areas. Urban participants are, on average, able to save 0.67 euro per week (from 7.51 euro to 6.84 euro), which is a reduction of 8.9%. Participants living in suburban or rural neighbourhoods, only save 0.13 euro per week (from 9.72 euro to 9.59 euro), which is only a reduction of 1.3%. This suggests again that urban participants are more capable of changing their travel patterns compared to rural and suburban participants, at least on the short run.

3.3 Additional changes in travel behaviour

There are numerous ways in how people can reduce their travel costs induced by road pricing. 28% of the participants state that they have – at least three times during the road pricing period – combined different trips. 19% of the participants state that they walk or cycle more as a result of the road pricing, while 10% state that they choose closer shop destinations. The top five of ways to limit travel costs is completed by shopping at cheaper times of the day (10%) and choosing cheaper types of road (7%) (Figure 4). These are all travel behaviour changes which can be accomplished on the

[6] Of course, only in the case road pricing results in less congestion (see also Section 4).

short run and which are easier to realise for people living in urban neighbourhoods than people living in rural/suburban neighbourhoods. As urban neighbourhoods have a higher density and diversity, more amenities are nearby, making it possible to travel short distances and travel with non-motorised travel modes.

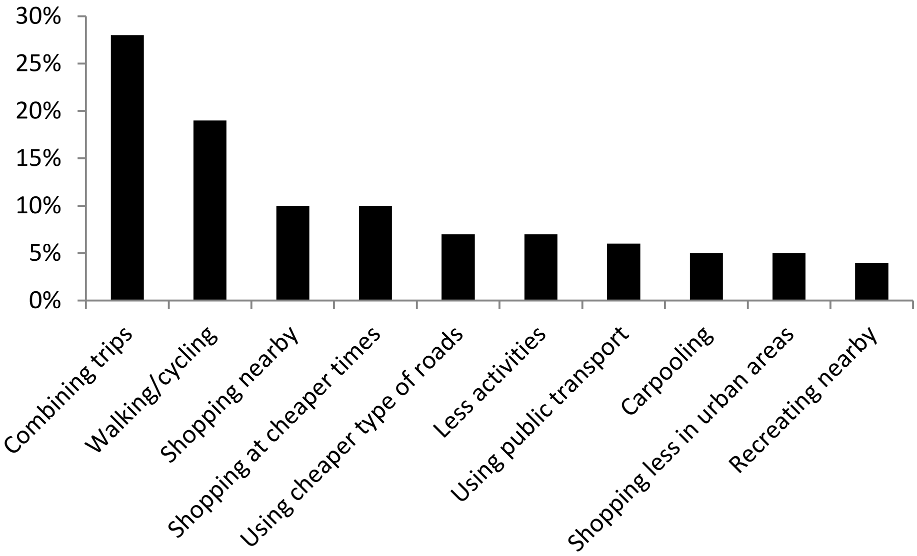

Figure 4. Percentage of participants adapting their travel behaviour in a certain way at least 3 times during the road pricing period (Source: Viapass, 2014)

4. Limitations

Unfortunately, the performed pilot project has some limitations. First of all, participants of this project only experienced the negative aspect of road pricing (i.e., the charge per kilometre travelled), but did not experience the positive effects of road pricing. As only a marginal share of the total road users participated in the project, the positive effects on congestion and travel time are negligible. As a result, an overestimation of participants' change in travel behaviour might have occurred, as more people might have decided to pay the charges in case road pricing resulted in faster travel. Another consequence is that only 26.0% to 29.4% (depending on type of road pricing (i.e., time; place; time and place differentiating)) of the participants state that they would choose *probably yes* or *definitely yes* in case a referendum would ask them whether or not to implement a road pricing regime. As public support can be an important element in the actual implementation of road pricing (e.g., Smirti et al., 2007; Vonk Noordegraaf et al., 2014), participants of this project and also other inhabitants of Belgium need to be convinced of the benefits of road pricing. However, Börjesson et al. (2012) indicate that public resistance before the implementation can be changed into a (small) majority being in favour of the charges after the implementation.

Second, as participants exceeding their virtual travel budget did not have to pay extra, there also exists a certain underestimation of the car-use change. After reaching the budget level, participants were no longer stimulated to (i) reduce their kilometres travelled by car, (ii) avoid driving in peak hours or (iii) avoid using certain type of roads. This can complicate conclusions and potential policy recommendations based on the results of this project. Furthermore, people might respond differently to a financial reward, as is the case in this pilot project (when driving less − or choosing cheaper times and roads – than during the pre-treatment period), compared to being charged for road use in case of an actual implementation of road pricing.

Third, as one of the conditions to participate was to own a car, urban residents – which are characterised by a lower average car possession − are underrepresented. This could also be one of the reasons of the low acceptance levels of road pricing as urban residents have on average more benefits of road pricing as they travel less by car and are more affected by road congestion, air pollution and noise pollution. Furthermore, people with a rather neutral or lukewarm attitude towards mobility and road pricing and people with limited access to a (cell) phone are probably also underrepresented in this project.

Fourth, as the road pricing period of this project only took eight weeks, participants could only adapt their travel behaviour to a limited degree. On the short run, people can change elements like the time of departure, mode choice and route choice. Results show that people who already live in an urban neighbourhood (with a lot of travel opportunities), people who have a season ticket for public transport and people who are already familiar with carpooling before the project are more able to adapt their travel behaviour than others. However, as a lot of travel-related aspects are linked with long-term decisions such as car ownership and the residential location choice, a lot of travel behaviour changes would only become visible after a certain amount of time. It is possible, for instance, that people will look for a closer job or will relocate to urban areas (where average distances are shorter and alternatives for the car are mostly present) in order to reduce travel costs. Furthermore, as the pilot project only took 12 weeks (i.e., pre-treatment and road pricing period), the effect of fluctuations of fuel prices on the use of charged roads could not be measured[7]. Rising fuel prices are expected to have a positive effect on toll road use. As these roads are mostly less congested and often shorter than non-toll routes, the use of toll roads can significantly reduce travellers' fuel costs (Huang and Burris, 2015). As indicated before, the relatively short project period made it also difficult to implement seasonal differentiations in the road charges.

5. Possible alternatives

It is expected that the proposed road pricing regime – with the highest charges for using urban roads − will result in less car use and travel time losses in cities, consequently contributing to the liveability and attractiveness of residential neighbourhoods since, among others, air and noise pollution will reduce and road safety will improve (Beevers and Carslaw, 2005; Eliasson et al., 2009). Some undesired effects, however, some of which may well be underestimated by policy-makers, may occur. First of all, high charges for using urban roads or alternatively a cordon toll for entering city centres might result in accelerating urban flight of some groups. In particular households with a very mobile lifestyle might decide to move out of the city in order to reduce their travel costs (Banister, 2002), while retail inside toll zones might experience a negative impact on sales (Quddus et al., 2007). At the other hand, households which are less car oriented, while appreciating an urban atmosphere, may be inclined to move to the city. However, the proposed tariff differentiation which is in favour of the use of motorways, in contrast with the use of urban roads, will not discourage

[7] From mid-January until mid-April 2014, fuel price fluctuations in Belgium were negligible (http://www.petrolfed.be).

long-distance travel and will not convince rural residents to consider living closer to city centres or change their job (location). Under the currently proposed scheme, people may change their departure time or travel route, but will most probably hang on to long-distance car use. Since distance is, besides mode choice, a main parameter in terms of environmental nuisance and fossil fuel dependency of transport (Boussauw and Witlox, 2009), we suggest an alternative (time-differentiated) road pricing scheme focussing on long-distance car travel and thus on non-urban roads. Doing so, long-distance travel would be discouraged and people might decide to relocate in favour of more compact, mixed-use neighbourhoods where travel costs are lower due to shorter average distances and the possibility to use alternative modes. As non-urban residents' travel behaviour is often characterised by long-distance car use[8], it might also be possible to increase fuel taxes as an alternative for charging road use. This would decrease the demand to travel and therefore reduce kilometres travelled by car (e.g., Sterner, 2007). Furthermore, this would be easier to realise than a region-wide road pricing system. Unfortunately, increased fuel taxes will not reduce congestion as efficient as a time- and location-differentiated road pricing scheme might. Additionally, car users are less likely to link driving behaviour to added fuel costs as fuel taxes are charged upfront, and increased fuel taxes are more likely to burden low-income travellers as they mostly have lower efficiency vehicles (McMullen et al., 2010; Welch and Mishra, 2014). Therefore, we suggest a time-differentiated charge per kilometre travelled outside urban areas, possibly by using on-board units (Table 4).

Some studies have analysed the link between road pricing and residential location choice and state that road pricing might not only affect short-term choices (such as travel mode choice, route choice and destination choice), but also long-term choices, such as the choice of residential and work location. Most of them state that road pricing will lead to high densities, mixed uses and compact development patterns. Although most of these studies are conceptual and theoretical, Tillema et al. (2010a, 2010b) − conducting a stated preference experiment among 564 car-commuting respondents in The Netherlands − indicate that about 5% of the respondents has a reasonably high probability of relocating and about 13.5% has a high probability of changing jobs (in favour of a more nearby job location) in case a road pricing measure were to be implemented. Arentze and Timmermans (2007) − using a stated adaptation experiment among 395 train and car users in the Netherlands − found rather opposite results. They state that 2.1% of the respondents would change their work location and 9.8% would change their home location. Anyhow, the studies of Tillema and colleagues and Arentze and Timmermans seem to agree on the fact that a modest share of respondents is willing to change their residential location. According to Eliasson and Mattsson (2001) − applying an estimation model on the effects of road pricing − high travel costs (including high travel times due to congestion and high monetary travel costs) will result in a concentration of housing and other facilities, while low travel costs will result in a dispersed land use pattern. They state, however, that an implementation of road pricing in a congested urban area will not necessarily result in more concentration, as decreasing congestion will result in lower travel times. This indicates again that road pricing focussing on urban areas is not always ideal as it will not reduce urban sprawl. Another reason why a focus on long-distance travel is interesting is that job mobility and residential mobility increase with increasing commuting distance (van Ommeren et al., 1999). As non-urban residents

[8] In this pilot project, non-urbanites travel 39.9% more kilometres per car during the pre-treatment period and 51.8% more kilometres per car during the road pricing period compared to urbanites (see Section 3.1).

have, on average, longer commuting trips, their job mobility and residential mobility will be higher. An increase in commuting costs of non-urban residents by focussing road pricing on motorways will increase the chance that they will change their job location or residential location. According to Tillema et al. (2010a), respondents who already have a reasonable high probability of relocating (e.g., due to high commuting distances) are especially likely to relocate as a result of road pricing. The implementation of road pricing can then trigger an actual relocation.

Since urban residents already make significantly more use of public transport and active travel (i.e., walking and cycling) compared to suburban or rural residents (e.g., Ewing and Cervero, 2001), and a large share of car use in urban areas is caused by non-residents, we suggest to charge non-urban dwellers for using urban roads and exempt urban citizens from this extra charge (Table 4). As a result, urban compaction strategies would not be undermined by road pricing policies, preventing outward migration or negative impacts on local retail. Furthermore, stimulating people to live in urban areas – by reducing relative travel costs of urbanites in comparison with suburban/rural residents – will also promote sustainable lifestyles, which includes climate-friendly mobility and reduced congestion, and which may generally lead to lesser environmental impact (e.g., Alberti and Marzluff, 2004) and improved public health (Ewing et al., 2003; Van Dyck et al., 2009). As a lot of non-urbanites commute daily to urban areas[9], it might still be appropriate to charge car use on urban roads for non-residents. This urban road use charge can have different executions. Implementing a traditional cordon charge for entering urban areas could be implemented, whereby non-residents pay a fixed charge (whether or not time differentiated) when entering a city centre. However, it is also possible to include parking policies in the road pricing scheme, whereby all the parking spaces in the city − including corporate owned parking lots − would be included in one comprehensive pay parking management system, whereby urban residents could benefit from parking lots at a reduced rate. Finally, it is also possible to charge non-urbanites per kilometre travelled on urban roads by using an on-board unit, as has been executed in the pilot project. The revenues of road pricing can be used in various ways (e.g., Eliasson and Mattsson, 2006; Giuliano, 1992; Small, 1992). First of all, it can be used to reduce the fixed car ownership tax in order to shift charges from car ownership to car use. Second, it can be used to stimulate the use of other travel modes by a further development of high-quality public transport and better walking and cycling infrastructure, mainly in urban settings. This measure might convince urban car drivers – who are exempted from road use charges in urban areas – to limit their car use. Third, the revenues can be used to develop additional dwellings in urban areas in order to stimulate additional relocation of rural and suburban residents to urban areas. These three revenue uses of road pricing will discourage car use even further (besides the actual road pricing) in favour of alternative − and more sustainable − travel modes (i.e., public transport and active travel), and will consequently reduce congestion and air pollution. Furthermore, these uses will distribute revenues across various groups and will not unduly burden low-income travellers or unjustly benefit higher-income drivers (Eliasson and Mattsson, 2006; Welch and Mishra, 2014). Finally, a part of the revenues can be invested in the maintenance and improvements of roads, as is commonly done in road pricing.

[9] For instance, approximately 240,000 inhabitants of Flanders and 130,000 inhabitants of Wallonia commute to the metropolitan region of Brussels every weekday (http://www.beldam.be).

Table 4. Proposed alternative road pricing scheme for urban and non-urban residents.

	Urban residents	**Non-urban residents**
Urban area	No charge	(Time-differentiated) cordon charge or charge per kilometre travelled
Non-urban area	(Time-differentiated) charge per kilometre travelled	(Time-differentiated) charge per kilometre travelled

6. Conclusion

In this paper we have analysed a road pricing pilot project conducted in a polycentric urban area in Belgium. Results of this area-wide, time- and location-differentiated road pricing project, commissioned by the three regional governments in Belgium, indicate that participants partly adapt their travel behaviour in a positive way. However, variations in these adaptations can be found, especially according to (i) the type of road and (ii) the residential location of the participants. The reduction in kilometres travelled by car on motorways is lower compared to other roads, and is even negligible during peak hours, while urbanites adapt their travel behaviour more (in a positive way) than suburban and rural residents. This indicates that the proposed road pricing scheme barely affects travel behaviour of non-urbanites who travel, on average, more kilometres by car and therefore contribute more to congestion and pollution. Executing this scheme nationwide would therefore probably not reduce congestion significantly, which can be seen as the main goal of an actual implementation. We therefore suggest an alternative road pricing scheme focussing on long-distance car use. Charging a fee per kilometre travelled outside urban areas might not only result in short-term changes (such as changes in departure time or changes in the route choice), but it might also result in long-term adaptations. People might decide to relocate to more urban areas where they can reduce their travel costs due to shorter average distances and the possibility to travel with other modes than the car. Additional charges for using urban roads might still be desirable in order to improve the liveability of urban neighbourhoods. However, as travel patterns of urbanites are less burdensome to climate and residents, people residing in urban neighbourhoods should be exempted from these additional charges.

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