Road Pricing in Luxembourg

Is it time for the City of Luxembourg to introduce a road pricing scheme?

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Economics Extended Essay

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1 Introduction

Road pricing is a personal interest: Being an avid cyclist, I am not fond of overly congested streets. Automobiles unnecessarily pollute the air, take up space, and waste people's time. Sadly, Luxembourg has a very car-focused culture. The ratio of automobiles to humans is approximately 0.81. Worse, each adult capable of driving (±450'000) has, on average, one passenger car or commercial vehicle. [1, p.11,32] [2] As of 2018, this is the highest number in the European Union. [3]

A high concentration of automobiles leads to many negative externalities, such as congestion (traffic jams) and pollution. In order to reduce automobile traffic in Luxembourg, there are many possible solutions, including the following:

- An automobile tax[1]
- Pedestrianisation[2]
- A carbon tax
- Alternating days for even and odd number plates[3]
- A road pricing scheme (e.g. congestion charge)

I chose road pricing to be the topic of my extended essay because it is both a promising option but also includes some interesting economic dynamics.

[1] A tax on owning a vehicle
[2] An absolute ban on automobile usage
[3] A few cities, such as Paris, have already implemented this.

There is also a large enough amount of previous schemes from which can be learnt.

Road pricing schemes (especially congestion charges)[4] are becoming ever more popular. Big cities such as Singapore, London and Stockholm already have well-established road pricing systems, with smaller towns now also falling into their footsteps.

While other cities have adopted this way of dealing with the negative externalities of road usage, the City of Luxembourg currently has no form of road pricing yet. Therefore, it is time to consider the viability of introducing a road usage charge in the City of Luxembourg, which is what will be explored in this essay.

2 Literature Review

2.1 History of Road Pricing

The notion of offsetting negative externalities through a tax was first introduced by Professor Arthur Pigou in 1920 [4]. While he does not yet explicitly mention road pricing as an application of the tax he defined, his work has served as the basis of most road pricing research. The term "road pricing" itself also was not coined until the late 1940s. In the 1960s, economists such as Reuben Smeed and Clifford Sharp published papers on the subject. [5] [6] The World Bank also published its research on the economics of road pricing. [7] The first successful real-world implementation of road pricing was

[4]Congestion charges are a particular form of road pricing. However, I'll be using "road pricing" and "congestion charge" more or less interchangeably since the congestion charge is the most common form of road pricing.

the Area Licensing Scheme in Singapore. [8] However, other schemes such as the ones in Hong Kong from 1983 to 1985 [9], and New York in 2007 ended up failing due to political opposition. Political opinion is one of the things preventing widespread adoption of road pricing.

2.2 Benefits of Road Pricing

Road Pricing has the potential to be highly beneficial if implemented correctly. It lessens traffic jams, which makes it more environmentally friendly (both because of decreased emissions and the use of less raw materials). Less traffic also improves the liveability of the city and may even reduce the number of traffic accidents.

The revenue generated from road pricing also contributes to government income, which enables higher amounts of investment into public transport.

2.3 Economics of Road Pricing

In economic terms, a road tax compensates for the costs to society induced by the negative externalities of automobile usage. The diagram in figure 1 illustrates how a fixed price road tax changes the market equilibrium for road "consumption". In the diagram, the demand for automobile usage (D) is plotted against the total supply of road space (S). The impact of the fixed price tax (T) is shown by the supply curve of the road space after tax ($S+T$). The two axes are Quantity of road usage (Q) and the price of usage (P)

Economic theory tells us that the total supply (S) is equal to the Marginal Private Cost (MPC) of road usage:

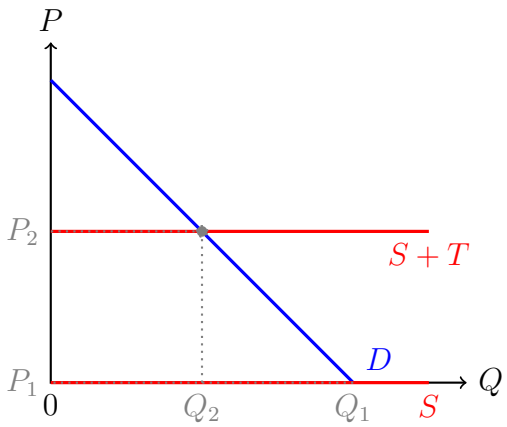

Figure 1: Graph of Fixed Price Road Pricing

$$S = MPC \tag{1}$$

However, this equation neglects the negative externalities of automobile usage to society (NE_A). If the negative externalities are to be included in our calculations, then we need to introduce a new type of cost, the Marginal Social Cost (MSC). It is equal to the Marginal Private Cost (MPC) plus the cost of negative externalities of automobile usage. Thus, we get the following definition:

$$MSC = MPC + NE_A \tag{2}$$

In order to fulfil its purpose, the road tax has to be such that it offsets the costs to society. This means that the Supply plus tax need be equal to the Marginal Social Cost.

$$S + T = MSC \tag{3}$$

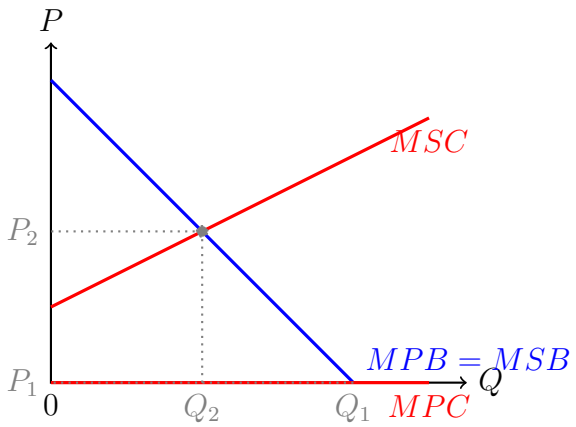

Figure 2: Marginal Cost Graph of Road Usage

In other terms:

$$T = MSC - MSB \tag{4}$$

Or most simply:

$$T = NE_A \tag{5}$$

The relationship between MPB, MSB, MPC and MSC is plotted in the diagram in figure 2.

In the diagram in figure 2, MPC is Marginal Private Cost, MSC is Marginal Social Cost, and MSB is Marginal Social Benefit. It shows Marginal Social Cost going up with Quantity. This increase is because an increase in road usage leads to an increase in congestion. Therefore, for each extra automobile using the road, not only the overall impact but also the marginal impact gets increasingly higher. Thus, a road tax in its most basic form creates a more sustainable equilibrium.

2.4 Existing Road Pricing Schemes

2.4.1 Singapore

The Singapore Area Licensing Scheme (ALS), introduced in 1975 [10], is the first successful implementation of road pricing worldwide. Initially, Singapore limited the congestion charge to the hours of 7:30 am to 9:30 am. However, since 1994 the charge has been in effect the entire day (24h).

The number of vehicles entering the road pricing zone after the introduction of the ALS (a 76% reduction) in 1975 was 7'700, compared to 32,500 before the ALS. 9% of people switched to public transport, while the rest either reduced trips or started car-sharing. Public transport usage also sharply increased for work-related trips to the city centre (from 33% to ±70%).

In 1998, a fully automated system named ERP replaced the previous manual ALS. Again, Singapore was the first city worldwide to introduce an electronic system to collect road user charges. Consequently, vehicles no longer had to stop or slow down to pay tolls. Users need only install a signalling chip on their car's dashboard or windscreen, a system similar to the french highway toll. ERP also extended the toll to motorways. Singapore once again extended the area in 1999. [11]

2.4.2 London

The planning of the London congestion charge started in 1965, one year after the publication of the Smeed report [5]. Additional studies were undertaken in 1973 and 1995.

London finally introduced its congestion charge scheme in 2003, and, at

the time, it was the most extensive road pricing scheme in the world. To make the transition to the charge run as smoothly as possible, Transport for London (TfL) increased the number of buses in circulation to cope with the anticipated increase in public transport usage. However, due to the inelastic nature of car usage, the congestion charge did not lead to a significant decrease in automobile usage.

On the first day, traffic decreased by approximately 25%. In part, this was due to it being a school holiday (traffic increased by 5% again after the holiday). The impact was most pronounced on the number of trips outside of the rush hour, while there was no significant impact on rush hour traffic. On average, journey times became ±14% shorter. The amount of fluctuation of travel time for a specific route also saw a decrease.

> "Congestion has reduced by 30 per cent in the zone."
>
> Transport for London, 2004 [12]

In consequence, public transport usage increased by approximately 12%. ±9% of automobilists avoided the zone by day or chose to travel after the hours the charge was in effect. Car-sharing increased by ±4%. The use of both motorbikes and bicycles also increased.

The decrease in traffic also meant less pollution, 12% according to TfL:

> "Traffic emissions are down 12 per cent."
>
> Transport for London, 2004 [12]

Initially, the scheme was incurring losses, since building the infrastructure required for efficient road pricing cost more than the revenue generated from charges. However, in the long run, the scheme was still successful.

Lastly, contrary to the predictions, the decrease in automobile usage did not result in a significant decrease in sales for the shops inside the road pricing zone. This shows that some common fears around road pricing are not necessarily valid.

2.4.3 Stockholm

The Stockholm road pricing scheme started as a seven-month trial (from 3 January 2006 to 31 July 2006). However, it turned into a permanent implementation in August 2007. The congestion tax was established to reduce traffic, especially congestion, and to improve the Environment in central Stockholm. The income from the scheme was to be used to build new roads in and around the city.

The 2006 seven-month trial reduced traffic by approximately 25%, a decrease similar to that of London.

In September 2006, a referendum was held about the permanent implementation of the road pricing scheme. The residents of Stockholm municipality voted in favour, whereas the other 14 municipalities in the greater area voted against it. The permanent implementation of the congestion tax was approved in 2007 and went into effect promptly.

The charge ultimately seems to have had a positive impact, since in 2016, the City of Stockholm further increased the price of their road usage charge in the inner city.

3 Hypothesis

Based on the available literature and case studies of applications in other cities, The following hypothesis can be made:

> Introducing a road user charge will have an overall positive outcome due to a decrease in automobile use. Consequently, it will decrease negative factors such as pollution and time waste through traffic jams.
>
> However, road pricing may cause a (further)[5] increase in social inequality, due to the affordability of driving a car going down and limitimiting driving to the wealthy.

This hypothesis will be tested in order to find out if it applies to the implementation of road pricing in Luxembourg.

4 Available Data

Luxembourg City currently has no form of road pricing. There is, however, a nation-wide annual tax on owning a vehicle. A national road toll for trucks weighing more than 12 tons [13] is also in place (the toll amount depends on the truck's size and its vehicle emissions class). However, none of these has a widespread impact on daily automobile usage.

Luxembourg's situation is unique when it comes to traffic. Approximately 206'000 people living in Germany (47'500), France (105'200) and Belgium

[5]It could be argued that driving a car is already considered a status symbol.

(48'100) work in Luxembourg during the day. [1, p.15] This leads to Luxembourg's population (626'100 [1, p.11]) increasing by a third by day. The vast majority of the frontaliers[6] work in the City of Luxembourg, meaning the city's population (122'300 in 2020 [1, p.14]) almost triples during the day.

The significant increase in population during the day leads to many more automobiles using Luxembourg's roads than for which they have been designed. This phenomenon can also be observed in large cities such as London or Paris. However, in relative terms, the scale in Luxembourg is much larger.

There have been plans to extend the road network. However, such a plan is impractical due to high resource requirements and the occupation of natural and inhabited land. Therefore, Luxembourg is stuck in a situation where it has too many automobiles, leading to excessive congestion.

A quick look at the geography of Luxembourg also sheds some light on the difficulties of dealing with traffic. The images in both figures 3 and 4 show the city of Luxembourg as seen through google maps at morning and evening rush hour, respectively. Suppose we define the city limits to be at the ring[7] In that case, there are three of the main ways of entering (ENE, S and W) that are completely congested. Other side roads can also be used, especially in the area from South to West, but these main arteries are jam-packed during rush hour. Even off-peak traffic on those roads can be significant at times.

Luxembourg also has a very car-focused culture. The ratio of automobiles to humans is approximately 0.81. At the same time, each adult capable of driving (±450'000) owns, on average, just under one passenger car or

[6]"frontalier" is the term commonly used to describe the workers from the neighbouring countries. The term originates from the french translation of "border dweller".

[7]The "ring" is the highway circling most of the city.

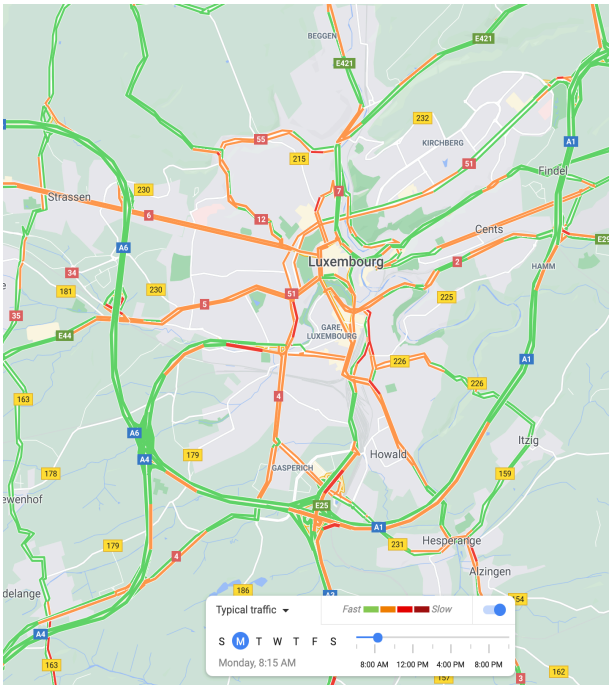

Figure 3: Congestion Heat Map of Luxembourg City in the Morning Rush Hour

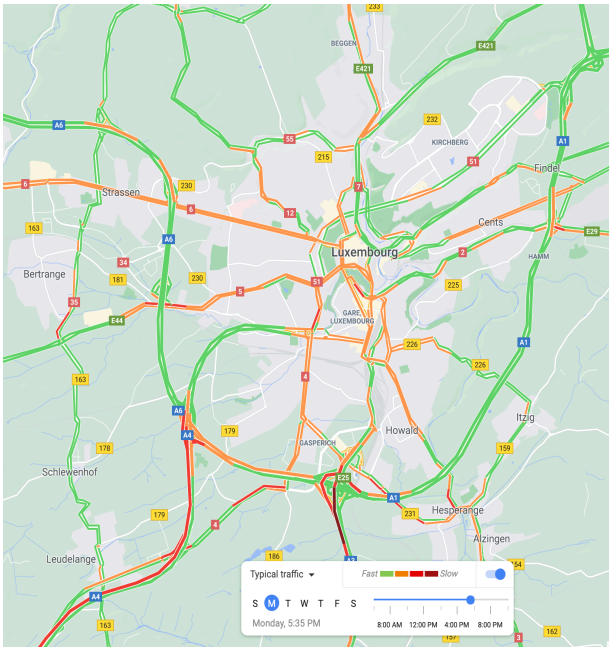

Figure 4: Congestion Heat Map of Luxembourg City in the Evening Rush Hour

commercial vehicle each. [1, p.11,32] [2] As of 2018, this is the highest number in the European Union. [3] This excess of automobiles results in below-average levels of car-sharing and many trips often made with one person per car. Since most cars have space for at least four passengers, this is a highly inefficient use of resources. Therefore, a road pricing scheme would have much potential in Luxembourg.

This excessive automobile usage leads to negative consequences:

- Roads account for 4.5% of Luxembourg's landmass (railroads account for a small portion of that figure) [1, p.5]
- Road-related deaths have decreased significantly (almost 75%) over the last 20 years. [1, p.20] However, Luxembourg is still one of the countries with the most road-related deaths in the European Union. [14] Non-fatal accidents have stayed more or less constant over that period, with ±1'300 people injured per year. [1, p.20]

5 Implementation Strategies

There are many ways of implementing road pricing. Since each city is different, the exact implementation has to be decided so that it works best for the particular case of the City of Luxembourg.

Luxembourg is a wealthy country and thus has an extensive public spending budget. This privilege allows it to fund large-scale, expensive projects such as a congestion charge since effective and efficient enforcement of a congestion charge requires specialised equipment such as advanced cameras and

number plate recognition software.

Based on this, there are a few solutions that can be applied. In fact, since each of the solutions has its positive and negative aspects, it is even possible to mix and match some of the solutions for a final hybrid solution.

5.1 Localised tax

One solution could be to only tax the usage of the main roads. In essence, this is a regular toll road. When analysing the map of Luxembourg (Figures 3 and 4), the main arteries become very apparent. The roads are marked from green to red depending on congestion levels. We can see that, during peak hour traffic, the main arteries are completely clogged.

Taxing the usage of these main routes would alleviate the traffic and improve transit times. Compared to some of the other solutions, this one would also have the added benefit of residents not being penalised for using their vehicle near their home.

However, a negative externality that this solution has is that day workers from outside the city will try to evade the tax by driving solely on side roads.

5.2 Floating tax

Another solution would be to have a floating tax, meaning the tax will only be in effect during the day when day workers from outside the city also use the roads.

This approach seeks to adapt to natural congestion periods in order to most efficiently tax road usage. Thus, the tax is higher when congestion is

thicker, thus only being in effect when necessary. Another benefit of this is that locals do not have to pay at night when the streets are less used.

It also has flaws. This approach only addresses the negative externality of congestion and disregards the pollution caused by automobile usage. Another problem with this method is the following. On Fridays and Saturdays, people from outside the city may wish to participate in the nightlife. A day tax would mean these people would be exempt from the tax, which may not be considered entirely fair. Additionally, locals would have to wait until the end of the tax period to be able to drive somewhere free of charge. Lastly, day workers may wait until the tax period is over before they return home, thus cheating the system.

5.3 Permanent tax

A blanket tax is perhaps the most promising tax since it treats everyone equally. Locals will be incentivised to use alternate forms of transport which, in most cases, is a net positive. People from outside the city will be incentivised to use the "Park and Ride" facilities instead of entering the city centre. A blanket tax overall a good approach since it addresses all negative externalities, unlike the floating tax.

Similar to the day tax, this tax form requires more resources to enforce since it is not just the main roads that have to be checked, but also all other roads. Thus even for the most rudimentary enforcement strategy (setting up toll booths at each entrance to the city), large-scale investments have to be made.

Time	Hourly rate	Total Charge
1h	€5	€5
2h	€10	€15
3h	€15	€30
4h	€20	€50

Figure 5: Example of an exponential tax

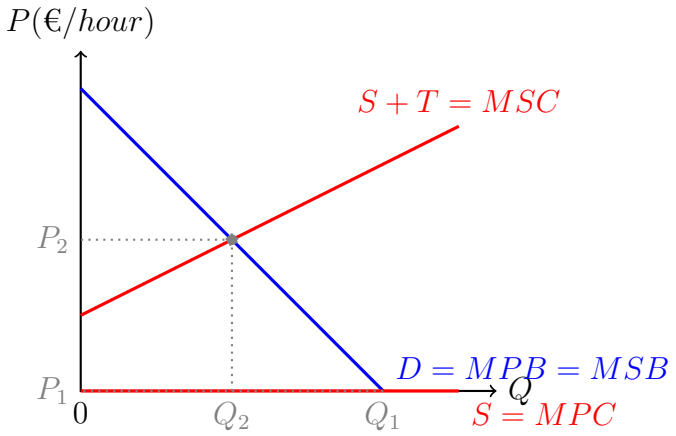

Figure 6: Diagram of increasing price Road Tax vs Marginal Cost

5.4 Exponential tax

For lack of a better term, an exponential tax is a tax that increases in size in proportion to road usage. An example of this is shown in the table in figure 5.

Compared to the fixed road tax (Figure 1), this approach is more efficient since the $S+T$ curve coincides perfectly with the Marginal Social Cost curve. The exponential tax is illustrated in the graph in figure 6.

An exponential tax can easily be combined with any of the others.

6 Predictions

6.1 Immediate Impact

Luxembourg's automobile usage is highly inelastic, even when compared to other countries. Nevertheless, we can assume that the impact of the road usage charge in Luxembourg is somewhat similar to that of London and Stockholm. Therefore, we can predict the decrease in daily automobile usage in the city to approximately 20%. Of course, all this depends on how the congestion charge is implemented since more aggressive pricing will have a higher impact. If we take London as an example, a 20% decrease in car usage will result in a around 10% increase in public transport usage. However, unlike London, Stockholm, and Singapore, public transport in Luxembourg is free. Thus, we can most likely estimate a higher increase in public transport usage.

Most of the main bus and train routes are already overcrowded during peak traffic hours. Therefore, even a modest increase would require a long-awaited restructuring of the public transport network. Fortunately, Luxembourg's public transport has seen some advancements in this area recently: the LUXTRAM project, which brought about decreases in road size in favour of tram tracks, bicycle paths, and larger pedestrian sidewalks. These changes have already brought about significant improvements in the liveability of the city. A road pricing scheme would also bring in road usage fees as revenue. This revenue contributes to the government budget and can be reinvested into the public transport sector and thus can be used to improve public transport infrastructure.

Luxembourg is also fraught with traffic jams, which results in people spending vast amounts of time in their automobiles. As we have seen, a road pricing scheme would decrease automobile traffic significantly (±20%), thus decreasing traffic jams. London's congestion charge resulted in a decrease in journey times of 14%, so we can assume the effect is similar in Luxembourg.

Less traffic also means fewer accidents. In London, traffic-induced accidents have decreased by 40% since the introduction of the congestion charge. Therefore, we can predict the decrease in accidents in Luxembourg to be similar than that of London.

Lastly, the impact on the Environment can also be reduced as a consequence of the decrease in private automobile usage. In comparison, public transport is more efficient due to its mass transport nature. Non-motor transport such as walking and cycling have a negligible environmental impact.

6.2 Social Consequences

It can be argued that a congestion charge could increase social inequality, due to it being a flat fee that the poorest cannot afford.

Fortunately, there is a solution to this. The social inequality of road pricing can be eliminated by using income-based tax (public transport will no longer be seen as "transport for the poor"). However, income-based taxing is more challenging to implement than a blanket tax.

Due to the "frontaliers", Luxembourg has its unique problems when considering a congestion charge.

- In general, the frontaliers are less wealthy than residents

- The public transport network is not as developed near the borders

Therefore, external workers will be impacted much more significantly than locals, which could be seen as a form of discrimination. Not only that but since many of Luxembourg's industries depend on the frontaliers, negatively impacting them could be detrimental to Luxembourg's economic growth. Of course, this could be alleviated by improving the public transport network near the borders. However, in the short term, this is not feasible due to the large-scale nature of such an improvement.

6.3 Political Viability

To determine the viability of road pricing in Luxembourg, it is necessary to analyse the public opinion concerning a tax on automobile usage.

Since Luxembourg's view on transportation has been mostly car-centric for many decades, a congestion charge would not necessarily be welcomed by all.

On the other hand, this mindset has been changing recently. There has been a significant rise in environmental activism, marked especially by the inclusion of the Green party in the national government. The Green party have been advocating for public transport improvements as their long-term transportation strategy. This plan has already been initialised through the (re)construction[8] of the tram, and the change has continued through the on-going expansion of the tram network. It is therefore fair to expect significant changes in public opinion in the future.

[8]The City of Luxembourg used to have a tram, but it was replaced in favor of road extensions for both automobiles and buses in 1964.[15]

However, since Luxembourg is still caught in the middle of this transition, it is yet unsure whether there would be a majority of supporters when proposing a road pricing initiative.

7 Conclusion

There remains much to be researched. Ideally, a proper field study should be conducted. However, overall, it seems that a congestion charge would benefit the City of Luxembourg in many ways:

- In the short run, there will almost certainly be a decrease in automobile usage. This decrease would result in a reduction of the negative externalities associated with automobile usage. Most likely, these effects will be most significant in the following cases:
  - Fewer accidents
  - Less congestion
  - Less pollution

  Consequently, the quality of life of Luxembourg City's residents will be significantly improved. Initially, a part of the population will be negatively impacted by a road tax, such as the less wealthy, who will be forced to switch to public transport.
- In the long run, these negative externalities should further lessen, due to the public transport infrastructure being further improved and extended. Improvements in public transport may result in a further de-

crease in automobile usage and could thus also lessen the negative impact of the congestion charge on the less wealthy.

While the benefits are clear, the question that remains is the following: *Will the Luxembourgish government begin considering road pricing as an option?*

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