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Towards a New Era in Road Pricing? Lessons from the Experience of First Movers

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Abstract/Résumé

Economists have long argued that road pricing improves the efficiency of infrastructure development. However, pricing projects for roads remain scarce, often for lack of political support. This research focuses on the mechanisms through which technological innovation, and, more specifically, the emergence of satellite-based navigation systems, contributes to the success of road pricing projects in four jurisdictions considered as first movers: Singapore, United States (Oregon), Germany and Norway. Interviews with local experts helped determine how the problem, policy and political streams converge to enable implementation of road pricing projects in these countries. The first movers' experience demonstrates that new technologies and increasing traffic problems are factors that contribute to an increasing need for pricing, but do not eliminate political hurdles. This suggests that it is better to plan things far ahead of time and move forward slowly in the hope of one day successfully implementing a road pricing project.

Keywords/Mots-clés: Road Pricing, Public Policy, Implementation, New Technologies, Window of Opportunity GNSS

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1. Introduction

Road pricing is not a new idea. It is based on a principle established by Adam Smith in 1776 that it is best to finance infrastructure projects such as roads and bridges through user fees. The benefits of this pricing are especially important considering that this infrastructure is subject to congestion and contributes to pollution. The work of Pigou (1920) showed, almost a century ago, that pricing can play a positive role in social welfare by generating the revenues needed to finance public infrastructure while reducing economic distortions caused by negative externalities.

Although this is an interesting idea in theory, road pricing schemes remain scarce. The congestion charge introduced in London in 2003 generated a lot of interest (Hensher and Puckett 2007), but several projects developed subsequently elsewhere in the world have failed (Gu et al. 2018, Rigot-Müller 2018, Ardiç et al. 2015, Vonk Noordegraaf et al. 2014). Many authors have raised the issues of political deadlocks and social acceptability, and have tried to identify the success factors related to road pricing implementation by focusing mainly on congestion pricing (Gu et al. 2018, Sørensen et al. 2014, Vonk Noordegraaf et al. 2014, Anas and Lindsey 2011, Albalate and Bel 2009).

The increasing use of global navigation satellite system (GNSS) by road users opens up new opportunities for road pricing (ITF 2019, Qin et al. 2017, Tan et al. 2017, Velaga and Pangbourne 2014, Numrich et al. 2012). Historically, tolls have been limited to bridges, tunnels, highways and urban cordons, but can now be collected on all networks and adapted to all road configurations using GNSS. No longer limited to toll booths, pricing now includes more options, including distance-based toll schemes often referred to as a "kilometer tax" (or "mileage tax" in the United States). The new technologies associated with this type of pricing make it possible to adjust toll rates based on location, time of day or type of vehicle in order to account for road wear and tear as well as congestion and pollution. Can these new opportunities revive interest in road pricing projects around the world? Is this the dawn of a new era in road pricing?

Switzerland and Germany were the first countries to use GNSS technologies to price heavy vehicles nationally in the early 2000s. Since then, several countries such as Slovakia, Hungary, Russia and Belgium have rolled out their own systems, (European GNSS Agency, 2015). Singapore is the first country to try to extend this form of pricing to all types of vehicles, including private cars. Their system will be implemented in 2020 (ITF, 2019). However, the coverage of their network remains partial, as only the road sections affected by congestion will be subject to pricing. Several American states, including Oregon and California, have also implemented pilot projects since the early 2000s to price all types of vehicles throughout their road networks (Duncan et al. 2017, ODOT 2017). Several other countries such as Finland, Denmark, the Netherlands, Belgium, the United Kingdom and Spain have also considered the possibility of setting up pricing systems for cars, but have not taken any action (European GNSS Agency, 2015). The Netherlands, in particular, actively researched this matter in the 2000s (Verhorf et al. 2008), but given the lack of political support, no project was implemented (Ardiç et al. 2015).

The emergence of new technological tools is not the only reason why road pricing is being reconsidered. Vehicle innovation is also driving public authorities to adjust their policies. The emergence of electric cars and, soon, autonomous vehicles, is causing the financing and management of roads to be rethought (Millard-Bal 2019). Road financing based largely on fuel taxes is not a long-term sustainable financing solution, hence the need for alternative solutions (Dumortier et al. 2017, Gomez and Vassallo 2013).

This paper focuses on the mechanisms by which technological innovation contributes to the success of road pricing projects in countries that have implemented such systems nationally. Four such countries are studied: Singapore, United States (Oregon), Germany and Norway. They were chosen because they have pricing projects that leverage technological advances and innovative practices, and because the pricing systems implemented cover the entire jurisdiction. In addition to a review of existing studies on these cases, interviews were conducted in 2017 and 2018 with some 39 respondents, including those in charge of the transportation networks in each country, university researchers and interest group representatives. The purpose of these interviews was to identify the factors contributing to the optimal use of new technologies when implementing road pricing systems.

The second section of this paper provides an overview of the theoretical aspects relating specifically to road pricing, including economic benefits, social acceptability and the emergence of new technologies. The third section focuses on the conceptual framework based on the theory of political streams of Kingdon (1995) and the methodology used for data collection and analysis. The fourth section presents a brief description of the cases analyzed and some comparative data. The fifth and final section sets out the results of the analyses of the content of the interviews. Some points of discussion are also presented. The conclusion offers some avenues for future inquiry on the use of road pricing.

2. Technological prospects and road pricing implementation

Road pricing has been extensively discussed in the literature. There seem to be two areas of consensus: road pricing schemes have a positive impact on welfare when it contributes to reducing congestion and polluting emissions, but their implementation is hampered by social acceptability issues. The question is how much the latest technological developments can enhance benefits while limiting negative public perception.

2.1 The economic relevance of pricing

According to economic theory, the use of road infrastructure is optimized when users pay the marginal cost of road use. Pricing covers costs associated with infrastructure repair and maintenance, environmental externalities, road accident externalities and congestion.

Infrastructure depreciation costs and thus capital spending, on the other hand, are essentially fixed costs. These costs can be financed by fixed charges such as registration fees and motor vehicle taxes. However, for the busiest roads, congestion-related prices alone can be used to finance the cost of infrastructure, which does not necessarily require fixed charges (Small and Verhoef 2007). Although Anas and Lindsey (2011) have pointed out that congestion costs are the fastest growing costs but that congestion remains a local issue and generally affects only a small number of roads in a given geographical area, concentrated mainly in large cities. Therefore, congestion cannot contribute to road financing across a country.

Road pricing also has a double dividend effect (Fosgerau and Van Dender 2010, Fridstrøm et al. 2000). When road pricing is used to reduce other forms of taxes that cause economic distortions (such as income or consumer taxes), the best option may be to set the toll rate higher than the cost of externalities. Distortions caused by general taxes and negative externalities caused by roads are thus eliminated as the sums needed to finance infrastructure are collected, hence the concept of double dividend.

Pollution can be addressed through traditional financing tools such as fuel tax. Road safety issues can be internalized largely through costs associated with drivers' licences, private and public insurance, fines and penalties. However, it appears that the cost of congestion can only be internalized through road pricing (Santos et al. 2010, Anas and Lindsey 2011). Fuel tax revenues have also declined significantly in recent years, calling road financing plans in many countries into question (Dumortier et al. 2017, Gomez and Vassallo 2013). Pricing remains a relatively expensive source of revenue (ITF 2010), but recent technological innovations tend to reduce the cost of pricing (ITF 2019).

Several empirical studies have shown that road pricing improves welfare overall (West and Börjesson 2016, Börjesson and Kristofferson 2014, Eliasson 2009, Santos and Fraser 2006, Fridstrøm et al. 2000). The addition of public transit services generally enhances these benefits (Ahn 2009). However, most studies focus on congestion pricing projects in urban areas. In these cases, it is clear that reducing congestion is the main benefit of pricing (Anas and Lindsey 2011). However, pricing also helps to reduce carbon dioxide emissions (Cavallaro et al. 2018, Meurs et al. 2013). West and Börjesson (2016) showed that these benefits are crucial in areas where congestion is lower.

2.2 The problem of implementation

Despite its economic benefits, road pricing remains rare around the world. As several studies have shown, public opinion remains resistant to road pricing, even in countries where it has been in place for several years (Duncan et al. 2017, Agrawal and Nixon 2015, Odeck and Kjerkreit 2010, Jaensirisak et al. 2005, Schade and Schlag 2003). Not only is opposition to pricing strong everywhere, but those who oppose it are also more likely to take political action (Duncan et al. 2017). There are several reasons behind this opposition: redistributive effects, equity, complexity of systems and public perception of benefits.

As Sørensen et al. (2014) pointed out, charging tolls on previously free road space will always be controversial, as it leads to a redistribution of costs. Tolls on new facilities are more likely to be accepted because they are associated with new infrastructure (Sørensen et al. 2014, ITF 2018). Several empirical studies have shown that the people most likely to be affected by cost redistribution are also those most opposed to pricing (Rigot-Müller 2018, Gehlert et al. 2011, Gaunt et al. 2007, Jaensirisak et al. 2005). In order to succeed, it is better to target transit traffic. The burden on the citizens of neighbouring regions reduces the perception of redistributive effects on the local population (Levinson 2000).

The principle of equity is also often used to oppose pricing (Levinson 2010, Jaensirisak et al. 2005). Pricing is generally seen as a regressive tax measure which may include some progressive elements, especially when external environmental effects are taken into account (McInnes 2017). According to Eliasson (2016), road pricing mainly affects middle-class households. Indeed, regressive impacts are mainly observed in areas where the population is more dependent on cars (West and Börjesson 2017, McInnes 2017). According to Bonsall and Kelly (2005), distance-based charging would affect more vulnerable populations less than area tolls or cordons. In all cases, the regressive effects of pricing can be mitigated by complementary policies (Levinson, 2010).

The complexity of pricing systems also fuels public concern (Gu et al. 2018, Rigot-Müller 2018, Gaunt et al. 2007). This is particularly true in the context of dynamic pricing, where prices vary in space and time, and depending on vehicle type (Francke and Kaniok 2013). Policies aimed at replacing taxes with distance-based road pricing also receive little support (Ellen et al. 2012). People prefer paying fixed fees with which they are familiar, such as registration fees or conventional tolls, rather than new fees (Dill and Weinstein, 2007).

However, some authors have noted that support for road pricing is stronger when it involves environmental or transportation demand management objectives (Agrawal and Nixon 2015, Odeck and Kjerkreit 2010). Public opinion is also more favourable when revenues from the fees charged are reinvested in public transit (De Borger and Proost 2012). Acceptability remains low, however, if the public is not convinced of the charges' impact on the environment and congestion (Schuitema et al 2010, Gaunt et al. 2007). In these circumstances, trial periods can reduce uncertainty and increase popular support (Gu et al. 2018, ITF 2018, Hamilton et al. 2014, Schade and Baum 2007). A good communication strategy can also reduce uncertainty and promote the adoption of a road pricing policy (Vonk Noordegraaf et al. 2014).

2.3 The prospect of a new era

Road pricing can be implemented using a range of technologies. Instead of traditional toll booths, several countries are now using overhead gantries with transponder readers or license plate recognition technologies that have no impact on traffic flow. However, these are relatively expensive and require frequent maintenance (Tan et al. 2017). In addition, they only provide partial coverage of road networks, which often results in externalities being shifted outside chargeable areas rather than reducing costs (Anas and Lindsey 2011). The use of satellite-based positioning technologies makes new opportunities and broader coverage possible (ITF 2019, Qin et al. 2017, Tan et al. 2017, Velaga and Pangbourne 2014, Numrich et al. 2012).

According to Qin et al. (2017) and Velaga and Pangbourne (2014), the wealth of data collected by satellite-based positioning technologies could offer solutions to social equity issues and provide authorities with more detailed travel data. This information could help to further our understanding of transportation needs and desires, to model them more appropriately and to target future infrastructure investments. It could also help to develop better tools to facilitate behavioural changes to improve sustainable mobility.

Switzerland and Germany were the first countries to use GNSS technologies to price heavy vehicles nationally in the early 2000s. Since then, several countries such as Slovakia, Hungary, Russia and Belgium have rolled out their own systems, (European GNSS Agency, 2015). Several other countries such as the United States, Finland, Denmark, the Netherlands, Belgium, the United Kingdom and Spain have also studied the possibility of setting up pricing systems for private cars, but without taking any action (ODOT 2017, European GNSS Agency 2015). Singapore is the first country to aim to implement such pricing in 2020 (ITF, 2019). Could this be the dawn of a new era in road pricing? Will these technologies make implementing pricing projects less challenging? The next section presents the proposed approach to answer these questions.

3. Conceptual framework and methodology

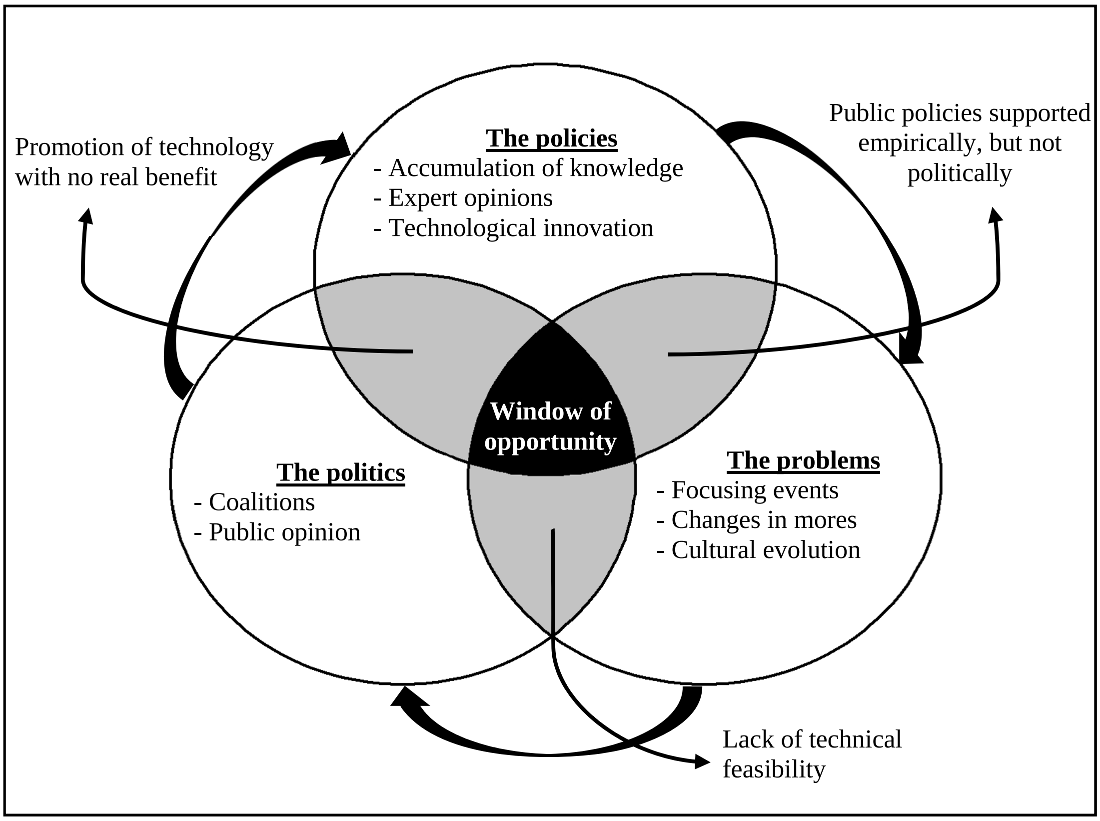
The conceptual framework proposed in this research is based on public policy theories. It aims to identify the factors leading to the success of pricing projects in four countries considered as first movers in road pricing: the United States (Oregon), Singapore, Germany and Norway. These cases are presented in more detail in the fourth section of this report.

3.1 Policy emergence process

As Feitelson and Salomon (2004) have already shown, it is not enough for innovation in transportation to be considered beneficial based on cost-benefit analysis criteria or to receive the support of a majority of the population. It will only be implemented if it emerges from the political process. Although ideas may be constantly promoted, they only become concrete policy proposals or investment priorities at specific times, which Kingdon (1995) refers to as windows of opportunity. Windows of opportunity generally open in response to events such as a change of government, or when programs or policies expire and need to be renewed. They are also influenced by problems that attract public attention (Birkman and De Young 2013).

According to Kingdon (1995), policy implementation is only possible when the three independent political streams illustrated in Figure 1 meet: the problem, the policy and the politics. The problems and the political context generally dictate the agenda, but public policies are mostly developed in the policy stream. The three streams converge when policy entrepreneurs intervene. More often than not, the policies precede the problems. Changes that occur at a time when a window of opportunity opens can lead to spillover effects. Once the basic policy paradigm is modified, similar changes may be introduced in related fields or in neighbouring areas. Policy evolution then takes an incremental form (Baumgartner and Jones 2009).

Figure 1 The Process of Policy Emergence



Source: Author inspired by Kingdon (1995)

The concept of a political stream has already been used to study road pricing projects. It was used by Dudley (2013) to analyze the implementation of the London congestion charge. He noted that the concept of a window of opportunity is not only important for our understanding of policy proposals, but also for the implementation stage. Ardiç et al. (2015) use this same concept to study the failure to implement the distance-based charging network in the Netherlands in 2010. According to these authors, the transformations required to implement pricing were so slow to materialize that the coalition of power behind the project was altered and the window of opportunity closed before the implementation phase. The same argument is raised by Rigot-Müller (2018) in the case of France that the window of opportunity may have closed before pricing came into effect.

3.2 Case studies methodology

Beyond the analysis of previous studies and official documents, this paper uses semi-directed interviews with government stakeholders, representatives of groups with a stake in the project and experts involved in the implementation of pricing in the countries in question. A total of 39 individuals from the four countries in question were interviewed between October 2017 and April 2018. In Singapore, where proceedings are more centralized and interest groups are less present, only six interviews were conducted. In Norway, where the management of road pricing systems is decentralized and interest groups are more present in the political arena, a dozen interviews were conducted.

Notes were taken during the interviews. These notes has been subjected to a textual analysis to identify the main themes of the discussion. The conceptual framework that led to the development of the interview framework and guided the thematic analysis is based on Kingdon's (1995) process presented in Figure 1. It aims to identify opportunities to converge the problem stream, the policy stream and the politics stream with a view to implementing road pricing policies in these countries.

These four countries were selected because they are considered to be first movers in road pricing. The characteristics that make these countries pioneers are presented in the following section.

4. Studied cases

The presentation of the cases is based in part on the content of the interviews conducted in each country and on existing studies.

4.1 Oregon’s distance-based charging system

Previous studies show that the main problem with road pricing in the United States is finding the necessary funds to finance infrastructure (Dumortier et al. 2017, Duncan et al. 2017, Gomez and Vasallo 2013, Dill and Weinstein 2007, Rufolo and Bertini 2001). Environmental issues or congestion do not appear to be important considerations (Anas and Lindsey 2011). It is in this context that several pilot projects have been launched in Oregon since 2006. The main objective of these projects is to replace the fuel tax with a distance-based charging system with equivalent revenue (ODOT 2017). Constitutional restrictions also stipulate that all funds collected from motorists in the State of Oregon must go toward road financing, making it more difficult to achieve objectives such as optimizing demand management or reducing polluting emissions.

The third pilot project implemented by the State of Oregon (the OReGO project) is now permanent and sanctioned by state legislation (ODOT 2017). This project involves nearly a thousand volunteers who pay a fee of 1.5 cents (USD) per mile travelled on the state’s roads (0.9 cents per kilometre) in exchange for a fuel tax refund. They can choose the pricing compliance terms by selecting the method for reading distances. Data on distances travelled can be collected using satellite-based positioning systems or other less intrusive means such as reading odometers manually. Pricing is done in partnership with the private sector, except for data management. Users are free to choose their service provider. The objective is to develop a competitive market for account managers (collectors), with a particular focus on diversifying roadside assistance services. The idea is to be open to several technologies and to remain flexible about the ways in which the tax is applied. Oregon's proposed pricing scheme applies only to private vehicles, given that the state already applies a distance-weight tax on heavy vehicles (Ball and Moran 2016).

Studies based on pilot project data have shown that pricing is slightly less equitable than the fuel tax (McMullen et al. 2010), but that it may be a good way to reduce congestion (Guo et al. 2011, Rufolo and Kimpel 2008). Pricing implementation is scheduled for 2025-2026. For the time being, it is the most successful distance-based charging system relying on GNSS technologies in North America.

4.2 Singapore's congestion charge

Singapore's congestion charge is among the oldest road pricing projects in the world, and probably the most studied one (Gu et al. 2018, Agarwal et al. 2015, Chu 2015, Vonk Noordegraaf et al. 2014, Albalate and Bel 2009, Anas and Lindsey 2011, Haque et al. 2013, Chin 2010, Olszewski and Xié 2005, Menon and Chin 2004, Phang and Toh 2004). A first manual system was implemented in 1975. It was replaced with an electronic system in 1998. Prices then became dynamic, rising gradually reaching their peak in rush hour and falling until the off-peak period. Traffic data is monitored and pricing is adjusted regularly (quarterly) to ensure that traffic flows efficiently (Phang and Toh 2004). Cars are equipped with transponders. Gantries are added on arteries that need them, depending on the speed of traffic. The number of gantries has increased from 32 in 1998 to more than 80 in late 2010. Management costs make up about 20% of the revenues collected (Menon and Chin 2004). The system has been effective in managing demand (Chu 2015, Olszewski and Xie 2005).

Tests were carried out in 2012 to replace the gantries with a system based on satellite positioning (Hiura et al. 2013). The contract for the commissioning of the new system has been awarded. The system is to be implemented in 2020. Singapore will be the first country to introduce GNSS-based pricing for all vehicles on its road network (ITF 2019). However, this pricing will only apply to road sections affected by congestion during peak period. This new technology will make it possible to collect more detailed data on congestion and manage infrastructure demand more efficiently.

4.3 Heavy vehicle pricing in Germany

Since 2005, Germany has been subjecting trucks of 12 tonnes or more to distance-based pricing on federal highways. Truckers are required to declare their itinerary. Most do this using an on-board unit that transmits satellite data to a central computer. A network of 3,000 terminals is also available on federal roads to register itineraries. This parallel network is necessary for trucks that are not equipped with an on-board unit. It also serves as a back-up in case the satellite network shuts down. Since 2015, the toll has been extended to vehicles of 7.5 tonnes or more, and, since 2018, it applies to all federal roads (40,000 km) in addition to highways (13,000 km). This network expansion has created technical challenges that have forced the centralization of data processing. Permanent infrastructure and mobile units have also been deployed on the roads for surveillance. All of this generates costs that represent about 12% of pricing-related revenues.

In its report, the Pällmann Commission (2000), which was behind the road pricing project in Germany, suggested to start by introducing a toll for heavy vehicles of 12 tonnes or more and then to extend the toll to lighter trucks and private cars (Doll and Link 2007). Several authors have supported the idea of extending pricing to private vehicles in recent years (Frey et al. 2015, Erdmenger et al 2010, Knorr et al. 2009). The policy response came from Bavaria with the proposal to require a vignette for private cars, similar to what is being done in Austria. This vignette should be introduced in 2020. It entails an annual charge for the right to drive on federal roads ranging from 67 euros to 130 euros, depending on the level of vehicle emissions. However, there is no distance-based charging system planned for private cars at this time.

Road pricing in Germany mainly concerns foreign vehicles, which contributes to its acceptability (Broaddus and Gertz 2008). According to Doll et al. (2016), the cost of tolls on heavy vehicles is passed forward such that the impact on the trucking industry is negligible. The overall effects of pricing on employment are even considered beneficial (Doll and Schaffer 2007). An environmental component is also added to pricing, and prices vary based on engine emissions. This tool is considered effective in accelerating the shift to cleaner technologies (Vierth and Schleussner 2012). As a result, the efficiency of road transportation in Germany has improved (Doll et al. 2016). To date, Germany remains the largest road pricing network and most important road pricing experience based on GNSS technologies in the world.

4.4 Financing pacts in Norway

Norwegians have been using tolls to finance roads for more than 60 years. Originally, these tolls were mainly used to finance the construction of bridges to replace ferries. Although bridges were more expensive, their benefits were greater, and since the ferries were not free, there was little opposition to bridge fees. Tolls spread in the 1990s and became real infrastructure planning tools (Lauridsen 2011). Since then, all new projects have been almost systematically subject to pricing. In cities, toll systems are organised in cordons. They are not linked to the financing of the infrastructure on which they are located. Instead, they fund pacts including several urban infrastructures for all modes of transportation, planned over a 20-year period. Norway is home to nine of these urban pacts.

Although part of a national policy, Norwegian toll systems are local initiatives. To access government subsidies, local projects must demonstrate that they can repay their loans through tolls within 15 years (sometimes 20 years). Prices are set accordingly and may be adjusted during that period. In urban areas, tolls are more permanent, but they are also used to finance loans for infrastructure development or upgrading. In 2010, tolls accounted for nearly 50% of road and urban infrastructure financing in Norway (Lauridsen 2011).

Gantries with transponder readers constitute the most widely used pricing technology in Norway. As a matter of fact, the city of Trondheim was the first in the world to develop this type of technology (Tan et al. 2017). Administrative costs of toll systems range from 12% to 23% of collected revenue depending on localities (Odeck 2019). The possibility of varying urban toll rates to factor in the effects of congestion and environmental policies has been considered since the early 2000s. (Larsen and Østmoe 2001, Odeck and Brathen 2002). The Norwegian toll system is considered a success because it enables work to start on infrastructure projects more quickly than the traditional method does (Odeck and Welde 2017). It forces planners to better anticipate traffic trends and therefore better assess needs, and allows a better return on investment (Odeck 2017). Road pricing has also increased the influence of local authorities on transport planning (Lauridsen 2011) and allowed the development of local expertise in road pricing technology (Ieromonachou et al. 2006).

4.5 Comparative data

Table 1 presents comparative data on the four cases studied. As one can see, with the exception of Germany, the selected jurisdictions have relatively small populations. They also all have developed economies, with a gross domestic product ranging from $40,000 to $75,000 per capita.

In terms of automobile use, there are significant contrasts. The proportion of vehicles per capita is only 0.145 in Singapore, while it reaches 0.989 vehicles per capita in Oregon, which is seven times higher. Automobile use is inversely proportional to the tax burden associated with owning and using a car. These taxes amount to $8,598 annually in Singapore, compared to only $381 in Oregon. They include vehicle purchase taxes, vehicle registration taxes and fuel taxes.

Table 1 Comparative Road Financing Data for the Four Jurisdictions Studied, 2017

	Germany	Norway	Oregon	Singapore
Population[1] (millions)	82.8	5.3	4.1	5.6
GDP[2] per capita (USD)	49,968	75,846	54,775	41,796
Vehicles[3] per capita	0.585	0.605	0.989	0.145
Fuel and vehicle taxes[4] (USD/vehicle)	879	1,713	381	8,598
Pricing[5] (USD/vehicle)	109	387	72	134
User contributions*/GDP (%)	1.16	1.68	0.83	3.03

Note (*): The user contribution is the sum of the tax and pricing revenues shown in the table.
Sources: 1- World Bank / US Census; 2- World Bank / US Bureau of Economic Analysis; 3- International Organization of Motor Vehicle Manufacturers / ODOT; 4- *Abstract of the Federal Ministry of Finance's Monthly Report January 2018* and *Environmentally related taxes in Germany* - OECD (Germany) / *Budget 2017* - Norwegian Ministry of Finance / *Annual Financial Report 2017* - ODOT (Oregon) / *Overview of the Budget for Financial Year 2017* - Government of Singapore; 5- *Budget plan 2017* - VIFG (Germany) / AutoPass 2017 - www.autopass.no (Norway) / *Annual Financial Report 2017* - ODOT (Oregon) / https://mothership.sg/2018/04/erp-history-20-years/ (Singapore).

As shown in Table 1, road pricing revenues are generally marginal in terms of total government revenues associated with vehicle use. The most significant pricing is in Norway, where $387 per vehicle is collected on the roads annually. In Singapore the amount collected is $134, in Germany $109 and in Oregon $72. Note that Germany and

Oregon currently charge only for heavy vehicles and Singapore only for congestion. Pricing in Norway is generalized to all vehicles.

The figures presented in Table 1 are consistent with the study by Gomez and Vassallo (2013). It should be noted that road financing in the United States is less dependent on user contributions. This suggests that a portion of the costs of the road network is financed by the public treasury (especially local roads, in the case of Oregon), while in Europe, and especially in Singapore, road revenues generate a net contribution to the public treasury.

5. Case analysis

The content of the interviews was analyzed to identify elements related to the political stream (presented in Figure 1). We highlighted these three streams in the stakeholders' discourses, starting with the policy stream.

5.1 Evolving solutions

In the countries studied, we can observe that toll networks tend to expand. In 2018, Germany added 40,000 kilometres of roads to its toll network. In Norway, the city of Oslo is increasing the number of toll points, with around 60 new stations planned for 2019. In Singapore, the implementation of the satellite pricing system will expand the toll areas. As for the state of Oregon, its distance-based tax will be applied on all roads, including local roads in 2025-2026. The types of vehicle subject to pricing are also increasing. In Germany, at the time of our study, the pricing applied only to heavy vehicles weighing 7.5 tonnes and over. However, discussions were ongoing on the introduction of a toll for private cars through the introduction of a vignette. Pricing for trucks from 3.5 tonnes to 7.5 tonnes was also under discussion. In Norway, electric cars are exempt from paying for the use of roads. However, this exemption will be withdrawn from 2020 in the city of Oslo. The Norwegian government is also studying the possibility of introducing distance-based charging for heavy vehicles like in Germany. In Oregon, heavy vehicles are already subject to a weight and distance tax. The authorities' goal is to extend the distance tax to private cars in the coming years.

The use of GNSS tools helps to expand pricing measures. Despite some difficulties between 2003 and 2005, most stakeholders agree that this system works relatively well in Germany. The recent centralization of data processing has allowed the toll network to expand at a relatively low cost. In Singapore, all the technological tests have been done. The technology is ready for the transition to the new system. In Oregon, legal and political considerations are the main issue. The technological tools are already functional. In Norway, the government is considering introducing satellite positioning pricing for heavy vehicles. Several stakeholders mentioned the fact that part of the pricing infrastructure in this country should reach its end of life within 5 to 10 years, which will provide an opportunity to migrate to new technologies. Researchers are already working on georeferencing the Norwegian road network to promote this opportunity.

In the four countries studied, the stakeholders agree that the future of road pricing depends on the development of simple solutions based on the use of cell phones and on the standard equipment embedded in cars to connect to GNSS. The challenge is to collect the data necessary for pricing in a way that respects privacy and to process it at a reasonable cost. For the time being, the cost of data processing remains an obstacle to the implementation of pricing. Experts argue that the costs of managing pricing systems far exceed those of alternative tax measures such as fuel taxes. As fixed costs are high, significant amounts of money must be collected on roads to justify the implementation of satellite positioning technologies. Many authorities are considering adding value to data collection by offering new services to users, but no such initiative has been successful so far.

Norway prefers for the time being to keep its toll system with gantries and transponders. The experience it has developed in managing this type of infrastructure has enabled it to substantially reduce its costs. According to Norwegian experts, migration to a GNSS pricing could only be done in collaboration with neighbouring countries in order to amortize fixed costs. For the moment, the Scandinavian countries each have their own pricing system. The technologies are compatible (with the Auto-Pass system), but data collection and processing is done locally. The European Union is trying to introduce standard pricing with the EETS (European Electronic Toll System), but negotiations are laborious. Many stakeholders would welcome the development of a Europe-wide satellite positioning pricing system, but it is still a fantasy. In the United States, the state of Oregon is working with the states of California and Washington. They share federal subsidies designed to make their systems interoperable, which could lead to economies of scale.

5.2 Finding the right problem

In Germany, Norway and Oregon, the need for infrastructure financing is at the origin of the road pricing system. In Singapore, the “user pays” principle also applies, but road pricing is not necessary given the scale of other charges already allocated to infrastructure financing (see Table 1). From one to another, users’ perceptions of their contribution to road financing may vary. In Germany, for example, not all stakeholders share the same view. Some believe that users’ contributions cover the cost of infrastructure, others believe that they do not contribute enough, particularly for the local network or the cost of externalities. In Norway, tolls were introduced at a time when the country was relatively poor to fill a gap in public funding for transport. Vehicle taxes were introduced to restore a precarious trade balance (in the 1950s and 1960s). Over time, these mechanisms have become recurring sources of revenue for infrastructure, leading local stakeholders to say that the “user pays” principle is well applied in Norway. The case of Oregon is a special one. In this state, it is the law that forces road financing on the basis of the “user pays” principle. However, the law applies only to the state budget and does not necessarily extend to the local network. It also restricts the use of funds from road user levies. These funds can only be used for road development, which makes it impossible to levy taxes to cover other types of costs such as congestion or pollution.

In Singapore, it is not the financing of the network that is behind the introduction of the pricing system, but the problem of congestion. Even in moving to distance-based charging through GNSS, the objective of transport authorities remains the same: to control traffic. The fact that pricing is a visible levy ensures that people become aware of the costs and adjust their behaviour, even if the congestion charge remains low compared to other costs. In Trondheim, Norway, as in Oslo, pricing has also been adjusted to take the effects of congestion into account. Although the system is not designed for this purpose, there is a reduction in automobile use during rush hour. Given the size of the Trondheim conurbation, congestion has never been a major problem, but it is enough in the eyes of the population to justify the modulation of charges. In Oregon, the state has received a grant to study the possibility of congestion charges, but the current legal context limits the possibilities. In Germany, the federal authorities do not even support the idea of congestion charges. According to them, because drivers are the only ones affected by congestion, there is no need to intervene. On trans-European roads, the European legislation is a constraint since all revenues collected on roads must be less than or equal to the cost of infrastructure. Thus, when traffic on a road increases, fixed costs are amortized over a larger number of users, and rates must be reduced. This is one of the reasons why charges have decreased in recent years in Germany.

Environmental issues are sufficiently important in Germany and Norway for road pricing to be adjusted according to vehicle emission standards. In Germany, the truck fleet was transformed by increasing the number of fuel-efficient vehicles (Euro 6). In Norway, environmental charge modulations are relatively recent. They aim to improve traffic flow and air quality in cities. Motorist groups in Europe are generally opposed to road pricing, but still support the idea that pollution costs should be borne by emitters. In Oregon, it is not believed that environmental costs can be included in road pricing. Popular support is too low. They have even recently adopted a tax on electric vehicles to compensate for the fact that they do not pay the fuel tax. Legal restrictions on the use of charges are also a major obstacle. Some point out that if a carbon tax is levied in Oregon, the revenues will have to be invested in road improvements, which is illogical.

For the time being, all stakeholders agree that fuel taxes support road financing relatively well and are an appropriate tool for combating polluting emissions. However, the development of electric cars is forcing the authorities to review their long-term financing plan. Norway is the country where these cars are most common. They receive several advantages: exemption from payment of excise taxes, fuel taxes, registrations and some tolls, in addition to discounts on ferries, other road tolls, parking, commercial vehicle taxes and access to transit lanes. Nor is there any sales tax on electric vehicles in Norway. But these privileges have been reduced over time and will have to be further reduced in the future according to local experts. In Oregon, the link between pricing and fuel tax replacement is explicit in the policy. Pricing is set to replace the current amount of fuel taxes.

5.3 Political and social acceptability

According to the participants in our study, several key elements must be in place to promote the implementation of a road pricing network: minimal impact on the local population, lasting political consensus, gradual implementation, easy to understand and privacy respect.

As already mentioned, one of the main obstacles to the implementation of pricing is the redistribution effect (see Section 2.2). To counter this effect when introducing distance-based charging for heavy vehicles in Germany, the government reduced the tax on the vehicles concerned by an amount equivalent to their anticipated contribution to the pricing. Only foreign trucks then absorbed the burden caused by the introduction of charges. The same mechanism is meant be used to facilitate the introduction of the vignette for cars, which has led to a conflict with neighbouring countries (Austria and the Netherlands). In 1998, Singapore did the same by reducing the road tax to offset the expected increase in charges associated with the implementation of the new electronic road pricing (ERP) system. At that time, the government also financed the in-vehicle units for all cars.

The successful implementation of a pricing project also requires strong political consensus around the project. In Germany, this consensus is strengthened by the fact that pricing revenues are dedicated to road financing. Under these circumstances, it is difficult to imagine getting rid of them. In Norway, some political parties advocate for free roads, but find it difficult to remove tolls when they come to power. In Trondheim, for example, the toll was withdrawn in 2005 and reintroduced in 2010. Getting rid of tolls is therefore seen as a losing political position. In Singapore, political opposition is low and citizens' confidence in their government is high. In this country, the debate on road pricing has been considered closed since 1975. The current debate is more about the reliability of new technologies and their costs. In Oregon, pricing support is less entrenched. The government supports the idea, but some fear that an election affects the progress of the project. Since the population is not yet directly affected, it is difficult to estimate the degree of real opposition. It is therefore in no one's interest to implement the pricing scheme too quickly.

Although there is little opposition to the new pricing system in Singapore, the government is considering doing things gradually. The new technology will require a period of validation and transition between the two pricing systems. In Trondheim, Norway, local actors advocate that public opinion adjusted after the introduction of the toll, once the benefits were noticeable. In Oregon, there have been several pilot projects. Trials on volunteer samples made it possible to identify small-scale problems and develop the necessary mechanisms to prevent these problems from occurring during implementation. All these interventions suggest that a gradual roll-out and trial periods are beneficial in the implementation of road pricing.

According to several stakeholders, the development of road pricing also stands to gain from incremental implementation. The first breakthroughs would open the door to broader pricing. In Oregon, many agree that the most difficult thing is to implement fixed-rate distance-based charging for cars. Once pricing is implemented and stabilized, it will then be possible to explore other avenues. The new House Bill 2017 now recognizes congestion as a problem in the Portland metropolitan area. In the longer term, this problem may be considered in pricing. Many people think the same thing about the introduction of the vignette in Germany. This is a way to migrate from free to toll roads. A paradigm shift is taking place in public opinion. Many see this as the next step after the implementation of distance-based charging for heavy vehicles.

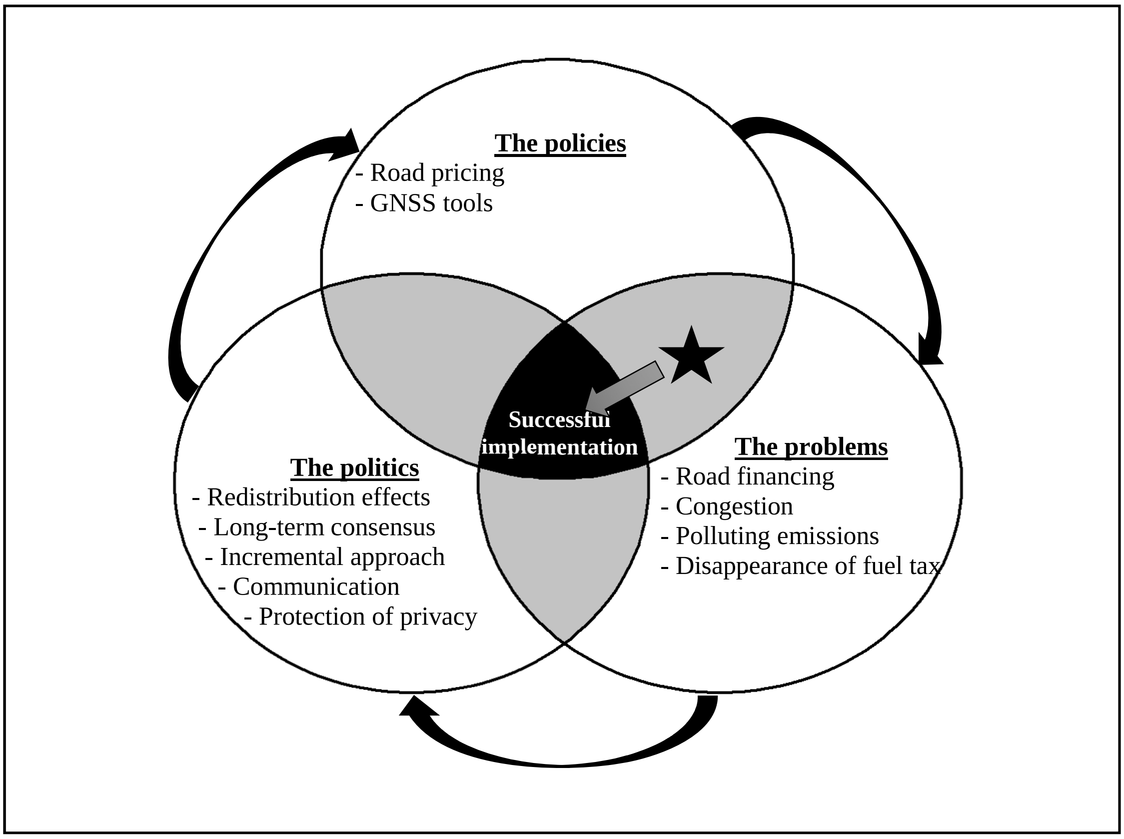
For the pricing system to be accepted by the public, users must have confidence in the accuracy and reliability of the data and be informed about the use of revenue. The system must be fair to them, whether they drive on local or national roads, in electric vehicles or heavy vehicles, in cities or in rural areas. The system must also be transparent to allow them to adapt their behaviour. This is a major challenge when it comes to configuring charges. In Norwegian cities, for example, users are subject to a multitude of fees that are not always harmonized. Although the system is easy to use, transmitting information to users remains a challenge. In Singapore, the migration to GNSS pricing will lead to the disappearance of ground infrastructure. If users no longer see the payment gates, there is a fear that they will no longer be able to understand the system.

Satellite positioning technologies are also more intrusive than standard pricing methods. The mass of data collected raises the question of privacy. In all the countries studied, laws protect private data. Managers of pricing systems, whether public or private, all have an obligation to collect only the data necessary for pricing and to destroy it after use. In Germany, operators are allowed to use aggregated data for statistical purposes, but cannot use it for research. In Norway, the police, who were initially not supposed to have access to toll data, were able to make requests to use information. According to local stakeholders, the population of Singapore is less sensitive to privacy issues. As long as access to public transport is widespread and allows anonymity in travel, there is no obligation on the part of the state to guarantee the same for motorists. In Oregon, private companies manage the personal data used for pricing. They can use it to develop services for members if the members agree. Users are free to choose the company to which they wish to entrust their data. This choice helps to increase public confidence. It is also important in Oregon to maintain an option free of localisation for data reporting, such as odometer readings.

5.4 Summary and discussion

As discussed in Section 3, it is possible to reach the implementation stage of road pricing projects when the three streams of policy, problems and politics are combined. This situation is illustrated by the central intersection of the Venne diagram in Figure 2. To achieve this, the policy solutions identified must respond to a real and perceived problem. As mentioned by Santos et al. (2010) and Anas and Lindsey (2011), the congestion problem is probably the one that best corresponds to pricing. By focusing on this problem, Singapore appears to be making faster progress. Congestion is clearly a national issue and pricing is the only tool to mitigate its costs. This issue is not as important in other jurisdictions that include large rural areas. The disappearance of fuel taxes is also seen as a major problem by the stakeholders we met, but this problem is not necessarily yet perceived by the population. That is why the Oregon project, which focuses on this issue, is taking longer to implement. In the cases of Norway and Germany, the primary reason for pricing remains infrastructure financing. In Germany, it is not clear that this reason alone will allow road pricing to be extended to private cars, while in Norway, tolls are increasingly used for demand management and environmental policies. It must be said that environmental problems stimulate popular support for pricing measures more than financing needs (Agrawal and Nixon 2015, Odeck and Kjerkreit 2010). This is probably what is allowing pricing in Norway to grow.

Figure 2 Summary of Political Streams Associated with the Implementation of Road Pricing Projects



Source: Based on the Kingdon (1995) model adapted to road pricing issues

Our interviews confirm what the literature has already been stating for several years: the key step in the implementation of road pricing projects is in the political stream level. In many cases, projects stagnate at the conjunction of policies and problems. These projects are mainly backed by experts. They respond to issues that are truly perceived by the population, but without political support or favourable public opinion. This situation is represented by a star in Figure 2. In Oregon, although there is political support for the pricing project, it remains unknown to the public. Some fear that political consensus is too fragile to make pricing effective for all vehicles. The challenge of privacy may well have been overcome at the technical level, but it is not certain that it will be overcome at the social level, where public opinion is being formed. This is the same issue that emerges in the debates on private car pricing in Germany. There is no consensus on this project. The only hope of seeing distance-based charging on federal roads in Germany extended to private cars is the incremental approach initiated by the vignette and the rise of environmental concerns. In Norway, it is the migration to a new pricing system based on GNSS that is struggling to find political support. There are fears that technological change will undermine the existing consensus. For this reason, Norway does not seem in a hurry to integrate new technologies into its pricing system, which works relatively well in its current form.

Pricing management costs also remain an obstacle. As mentioned in Section 4, there is no case of pricing among those studied here whose management costs are less than 10% of collected revenues, which is still significantly higher than the costs of other conventional road financing models (Santos et al. 2010). If there are no environmental or congestion reduction benefits to improve pricing, it is very likely that this method of financing will never be relevant. In a context where new technologies can help reduce pricing costs and the cost base of fuel taxes is slowly disappearing, it is important to keep in mind, however, that the relevance of road pricing will increase over time, hence the importance of actively considering it.

In addition, the implementation times for road pricing are very long. Political consensus is difficult to maintain over such long periods of time. The experience of France and the Netherlands has shown that windows of opportunity, even when they open over an extended period, sometimes close before the implementation stage, destroying years of research and development (Rigot-Müller 2018, Ardiç et al. 2015). In Singapore, the process will have taken about ten years before the new technology is implemented. In Oregon, it will have taken more than 15 years between the first pilot projects and the implementation of the pricing system planned for 2025-2026. In Germany, the gap between the introduction of the toll for heavy vehicles and the introduction of the vignette for private cars was almost fifteen years. Although the decline in fuel tax revenues now appears to be an argument in support of the introduction of road pricing, it must be recognized that this phenomenon may be more prominent in about ten years' time. However, it is preferable not to wait so long before starting to think about the subject.

Finally, we note that governments must have something they can exchange in order to implement pricing policies that have redistributive effects. This has been done in Germany and Singapore through a reduction in vehicle taxes to offset the effect of road pricing. In Oregon, fuel tax is refunded to compensate for road pricing. In places where vehicle and fuel taxes are relatively low, the opportunities for compensation are more limited. This reality must be taken into account when considering pricing. It is therefore understood that for road pricing to be implemented, there must be traditional financing tools already in place that present enough of an exchange value.

6. Conclusion

The emergence of new technologies is creating new pricing opportunities. The problem of congestion is becoming increasingly prominent in large cities (Anas and Lindsey 2011) and the environmental challenges facing governments are leading to increased use of mobility management tools such as road pricing. Can we conclude that we are at the beginning of a new stage of pricing project development around the world? The experience of the first movers requires some caution in this regard. It is true that new technologies and the amplification of problems are factors that contribute to increasing the need for pricing, but they do not solve the problem of public opinion or political support. The development of pricing projects is slow and, as Kingdon (1995) argues, the political stream remains independent from the problem and policy streams. In the short to medium term, it would therefore be surprising to see an explosion in pricing projects around the world in response to the technological advances of recent years. Several pilot projects have been carried out in several places, but most have faced political challenges (European GNSS Agency 2015). Studies focusing on success factors of road pricing projects are therefore still relevant (Albalate and Bel 2009, Anas and Lindsey 2011, Vonk Noordegraaf 2015, Sørensen et al. 2014).

Although experts say that satellite positioning road pricing technology is well developed and can take into account privacy issues, large-scale use in the short term is not possible in most countries. It should be noted that no case of GNSS pricing has yet been applied to private cars anywhere in the world. Therefore, there is no research on the positive or negative impacts of such an initiative based on real data. The first test will probably be the one in Singapore. It will be ahead of the rest of the world, in 2020. We will be able to draw several lessons from this experiment. As the case may be, these tests will provide opportunities to increase public confidence in new technologies and understanding of the benefits they generate in terms of sustainable mobility management. In the meantime, projects in other countries are likely to develop slowly. All will seek to benefit from Singapore's experience.

Although there is no demand for the implementation of a road pricing based on GNSS technologies in most parts of the world, mobility policy makers should consider this issue. Infrastructure management is a long-term process. Technological change is pushing us towards new mobility paradigms. Pricing is one of the tools that should be developed in the future, even if it is done at a slower pace than the experts would like. Knowing that these projects can take up to a decade to materialize, even with the right conditions in place, it will never be too early to start thinking about the subject, especially in light of the mobility challenges that our societies will face in the coming decades.

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