The Integration of Road Pricing and Motorist Information Systems

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Road pricing is recognized as providing (in theory) the first-best solution to congestion. But because of public opposition its feasibility is regarded as rather low. On the other hand, motorist information systems are viewed as user friendly tools for enhancing road efficiency. A combination of road pricing and motorist information systems may be an attractive policy option.

Introduction

Congestion on roads is a pressing problem for most metropolitan areas around the world. Many instruments have been suggested to resolve part of the congestion problem. In this paper two of these will be addressed, road pricing and motorist information systems (MIS). The first is regarded by most transportation researchers as the best instrument; the latter is generally viewed as a user friendly tool for tackling congestion.

Much research has been carried out to analyse the impacts of these instruments in isolation. In this paper we will not add to this body of literature. In contrast, a preliminary investigation into the implications of a combined implementation of a road pricing scheme and MIS will be conducted. This is of importance for two reasons. Firstly, since the required technology to implement these systems is rather similar, an isolated analysis of these two technologies might underestimate the beneficial effects of these systems due to the fact that synergy effects with respect to costs are not taken into account. Secondly, in reality it is most likely that the government will tackle the congestion problem with some kind of package approach, i.e. a package that contains several instruments which will be implemented simultaneously. To analyse the overall effects of such a package it is important to address the interactions of the different instruments. A partial analysis might give a biased view of the impacts of the package, since, due to the interaction between the instruments, the overall effect is not always the same as the sum of the effects of the individual instruments.

Thus far, a few researchers have addressed the joint implementation of road pricing and MIS. De Palma and Lindsey (1992) built a simple mathematical model and concluded that for certain parameter ranges the simultaneous implementation leads to super additive benefits, i.e. the combined benefits exceed the sum of the individual benefits. Brett and Estlea (1989) argued that a combination of road pricing and MIS might be the ‘next step’ for two reasons.

Firstly, the basic technology involved in the two systems has enough common characteristics for it to be feasible. Secondly, it is not inconceivable that either route-guidance alone will be sufficient to prevent congestion from reaching untenable levels or that, by making better use of existing road space and reducing congestion in the short term, additional trips will be generated from the release of suppressed demand so that the onset of chronic congestion is hastened. (pp.245-246)

Verhoef, Emmerink, Nijkamp and Rietveld (1994) assessed efficiency and equity impacts of a combined pricing and information
system, using a stochastic economic equilibrium concept.

Following this relatively new stream in the literature, it is a useful exercise to investigate the implications of a joint implementation further. For a better understanding of the remaining part of the paper, the second and third sections briefly review the literature on the impact of road pricing and MIS in isolation. Since the literature in these fields is huge, the discussion will be confined to the positive and negative effects of the two instruments. The fourth section addresses the simultaneous implementation of a road pricing scheme and MIS. The structure of this section is similar to that of the second and third, i.e. the focus will be on the positive and negative effects of a joint implementation. The final section summarizes the main arguments. It is important to stress that the arguments provided in this paper are qualitative in nature. This paper serves primarily as a first investigation into the relevant issues.

Road Pricing

The theoretical concept of road pricing, stemming from Pigou (1920) and Knight (1924), and further explored by Walters (1961), Smeed (1964), Sharp (1966) and Vickrey (1969), is based on levying a tax equal to the difference of the marginal social costs and marginal private costs (Pigouvian tax). In doing so, the transport externalities are *internalized*, implying that the negative effects on other road users when joining a road are accounted for in the user’s decision-making process. In economic terms the road price ensures that only economically efficient trips are undertaken, and therefore, road pricing is called the *first-best* instrument to tackle congestion.

However, in Emmerink, Nijkamp and Rietveld (1994) it is argued that the first-best property of road pricing holds in a simplified theoretical framework; it may be hard to achieve in real-world applications. Hence for practical applications, road pricing should be viewed as just another *second-best* tool for resolving (part of) the congestion problem, although it may often be expected to approach first-best standards more closely than do other second-best tools. In the following, the positive and negative aspects of road pricing will be discussed briefly.

Advantages of Road Pricing

The first-best characteristic of road pricing which holds in a simplified theoretical framework is the major attractive property, i.e. the ability to attach a price to external effects. However, in practical applications, road pricing has four additional positive features. Firstly, being a financial instrument, road pricing addresses the problem of latent demand directly by using money rather than delays to ration road capacity, this in contrast to the more traditional solution of offering additional road capacity. Some of the positive effects of other available instruments for curbing levels of congestion (one should particularly think of efficiency improving measures) are taken away by the appearance of latent demand. Secondly, road pricing raises government’s revenues by taxing externalities rather than economic productivity. Inefficient use of scarce resources is penalized rather than economic productivity, which is widely being viewed as a good principle for taxation. Thirdly, road pricing provides the government with an opportunity to privatize (part of) the road network operations, and thus widens the scope of the government’s policy options. Finally, road pricing is often expected to outperform other (second-best) instruments, since the road price can differentiate to both distance travelled and time-of-the-day. This is in contrast to, for example, parking policies or fuel taxation.

Disadvantages of Road Pricing

Road pricing is a controversial policy, mainly due to the potential adverse effects
associated with implementing this instrument. Below, the most frequently mentioned disadvantages will be briefly discussed.

- Although road pricing maximizes (in theory) social welfare it does not lead to a strict Pareto improvement. Rather it leads to a potential Pareto improvement; the revenues obtained are in theory large enough to render each individual better off. In fact, even transportation researchers are not in agreement whether such a redistribution scheme is practically feasible.

- Road pricing touches the issue of freedom of road usage by individuals. Charging for something that was up to now free will negatively affect political support.

- The problem of rat-running appears high on the list of practical problems. Rat-running is the term referring to the problem of motorists trying to avoid the road price by driving on unpriced roads. It might be costly to devise a sophisticated system that leaves no possibility of rat-running.

- Road pricing might be perceived to serve different objectives by different groups of society. The government may perceive it as an instrument to increase social welfare and government revenues; environmentalists may view it as a means to stimulate carpooling and the use of public transport, and hence to reduce pollution and the need for new roads; while businessmen may perceive the road price as funding resources for new highways and continued economic development. The interests of the above mentioned groups do not necessarily converge.

- Road pricing will hit low-income groups hardest and hence might induce some form of inequity compared to the status quo. Additionally, it might induce regional inequality since a congestion charge is to be paid only in congested areas.

- The costs of implementing a (sophisticated) road pricing scheme should not be underestimated.

Motorist Information Systems

In this section the objectives and the strong and weak points of MIS are discussed. MIS are designed to provide motorists with useful information on the traffic situation, using new telecommunication and information technologies. Other well known terms are Road Transport Informatics (RTI), Intelligent Vehicle Highway Systems (IVHS) and Intelligent Transportation Systems (ITS). MIS refer to systems supporting the decision-making process of motorists only, while RTI, IVHS and ITS refer to a broader set of technologies relating to the network infrastructure as well. For instance, signal control, ramp metering etc. might all be part of a sophisticated RTI environment. Besides the fact that the exact definitions of the different terminologies (MIS, RTI, IVHS, ITS etc.) are unclear, there is a strong overlap between the technologies themselves. For instance, accident detectors might be used for the police and ambulance, but also for broadcasting information on accident sites.

Definition and Objectives of Motorist Information Systems

Throughout this paper, we will be solely concerned with information technologies for road users. As mentioned above, these are known as MIS, but also as Dynamic Route Guidance (DRG) systems or Advanced Traveller Information Systems (ATIS). These technologies are all based on the same principle: information on the situation in the road network is broadcast to the motorists in order to enable them to improve their travel choice decisions (Ben-Akiva, De Palma and Kaysi, 1991). The information provided and, as a consequence, the decisions affected might be concerned with mode, departure time, route choice, and even whether or not to travel. The purpose of these systems is to improve the efficiency of the road network. The most efficient use of a road network is in the literature defined as the system.
optimum, Wardrop's (1952) second principle stating that 'the average journey time is a minimum' (p.345).

Hence, the purpose of these new technologies might be stated in terms of the system optimum. These new technologies should help in directing the traffic flows towards the system optimum. However, since MIS do not influence network performance directly – they influence driver behaviour instead – it is not obvious whether the desired network performance will be reached. In fact, in Emmerink, Axhausen, Nijkamp and Rietveld (1993) it is argued that this is unlikely. MIS will direct traffic flows towards the full information user equilibrium (Wardrop's (1952) first principle), not towards the system optimum. MIS do achieve their objective when they decrease system transportation costs in the network, or even better, when they will lead traffic flows towards the system optimum. However, it can be shown (Sheffi, 1985) that the latter is not the case in congested networks. Mahmassani and Peeta (1993) underscored this point by using a new simulation-based algorithm for the time-dependent assignment problem and found that the discrepancy between the system optimum and the user equilibrium can be relatively large in heavily congested (though not over-saturated) networks.

However, using a randomization argument, some researchers have argued that reaching the system optimum might be feasible in practice. At the system optimum the average travel time is at a minimum; hence all road users have potentially something to gain. The fact that some road users are individually worse off could be avoided by taking a long-run perspective: if the road users who are worse off are randomized on a daily basis, then in the long-run they might realize that they are better off by complying with the information than by behaving in a selfish fashion.

Another argument in favour of reaching the system optimum makes use of drivers' travel time perceptions. It is questionable whether drivers are able to perceive small travel time savings. If not, then these modest savings leave some space for sending drivers to system optimal (individual non-optimal) routes (Van Berkum and Van der Mede, 1993).

To conclude, from a government policy point of view, MIS should help to bring traffic flows closer to the system optimum. The feasibility of this goal, however, remains debatable.

Why Design Motorist Information Systems?
The Advantages

Besides the previously defined main objective for designing MIS, three additional arguments in favour of implementing MIS may be put forward.

In the first instance, MIS are (if effective) a user friendly instrument for the car driver. Other instruments contain certain charging mechanisms and are clearly perceived as less popular among motorists. Conversely, MIS are designed to help motorists by improving their mode, route and departure time choices rather than by pricing them off the roads. In addition, it should be noted that even when MIS would not lead to better decisions by drivers, they may nevertheless be valued positively by their users because they make car use more comfortable.

Secondly, both the car manufacturing companies and the companies that manufacture electronic components regard MIS as a potentially large emerging market. Once these technologies have been introduced at a worldwide scale they might create a new industry and provide jobs for thousands of employees. Obviously, this is the major reason for these firms to join the on-going research programmes in this area.

Thirdly, governments consider MIS as a cheap alternative of capacity expansion of transport networks compared with the more traditional policy of constructing additional roads.

Finally, one of the major forces behind the introduction of MIS might be a technology-
push argument: the world is moving fast; new technologies are being implemented in most parts of society and have significant impacts on society. However, it seems that technology does not play an equally important role in the transportation field. Clearly, new technologies have been implemented in this area (for instance, one could think of more sophisticated traffic control systems, automatic vehicle detection, improved automobiles etc.), but the decision whether or not to carry out a trip and the decision on which mode, route and departure time to choose is essentially still the same as (say) 20 years ago. The traveller relies solely upon his own perceptions and (if available) some radio reports. Advanced information systems are not (yet) being used for these type of decisions. Trip decisions are taken mostly without any information on different alternatives, the current and past traffic situation etc. The current research efforts towards analysing the impacts of these information technologies in the transportation field (as for instance carried out within the EU DRIVE II programme) are making one believe that these technologies will penetrate into the transportation field eventually.

Potential Drawbacks of Motorist Information Systems

As argued on page 239, it is questionable whether MIS will be able to direct the traffic flows towards the system optimum. Even though the randomization and small travel time savings arguments are in favour of reaching the system optimum, it is most likely that due to short-run selfish behaviour the user equilibrium will be established instead. In fact, there is nothing wrong with this as long as MIS are able to substantially improve the present situation. Recent research by Emmerink, Verhoef, Nijkamp and Rietveld (1994) and Verhoef, Emmerink, Nijkamp and Rietveld (1994) suggests that MIS may achieve some 40 per cent of the (first-best) potential available welfare gains.

The successful implementation of any MIS might further be frustrated by the following two implications. In the first instance, the implementation of MIS might be very costly. Clearly, these costs are strongly dependent on the type of system and the level of sophistication. However, to diminish the potential adverse effects of over-reaction and concentration, recent research stresses the importance of high quality information (Ben-Akiva, De Palma and Kaysi, 1994; Emmerink, Axhausen, Nijkamp and Rietveld, 1994a, 1994b). Particularly when the level of market penetration of the MIS is substantial (e.g. the market penetration exceeds 20 per cent) this is an essential prerequisite since these adverse effects tend to increase with an increasing penetration rate of the technology (Mahmassani and Chen, 1993). Moreover, relatively unreliable information is one of the most important determinants of adverse systemwide performance of MIS at relatively high levels of penetration (Emmerink, Axhausen, Nijkamp and Rietveld, 1994a, 1994b).

Secondly, as with most second-best instruments, the potential beneficial effects of MIS might be frustrated by the appearance of latent demand. If MIS improve the network efficiency as is hoped they will generate more traffic on the roads, thereby taking away part of the beneficial effects (Emmerink, Nijkamp, Rietveld and Axhausen, 1994; Emmerink, Verhoef, Nijkamp and Rietveld, 1994).

To conclude, we might assert that MIS do potentially offer some quite beneficial effects to society. However, there are some potential adverse effects looming. Some of these are inherent in MIS, whereas the impacts of others may be mitigated by a careful design of the system.

Combining Road Pricing and Motorist Information Systems

The potential implications of a combined road-pricing scheme and MIS will be
presented below. First the importance of implementing a road-pricing scheme and MIS jointly is analysed, then the difficulties of doing so are discussed.

Advantages of a Combined System

If the objective of the government is to optimize traffic flows in a network, then it was argued on page 237 that MIS is most likely unable to do so. MIS will usually not be able to reach the system optimum when the network is congested; in these circumstances, the user equilibrium and the system optimum do not coincide and incentives to make motorists comply with system optimal routes are needed; a pricing incentive is the most obvious one. Viewed from this perspective, road pricing and MIS can be regarded as natural complements of one another.

It is clearly a matter of policy whether the government intends the system optimum to result on the road network. From an economic point of view it is desirable to use scarce resources, such as road space, as efficiently as possible, and hence the aim to reach the system optimum is a laudable one. However, most governments are reluctant to use the policy instruments necessary to reach this optimum. The explanation of this behaviour may be traced to the complexity and (often) unpopularity of active transportation management in general, and of road pricing in particular (see pages 237 and 238).

Complementary Technologies

However, if the government decides to adopt an active transportation management policy and commits itself to using road space as efficiently as possible (thus approximating the system optimum in the road network), then road pricing and MIS are important complementary technologies. MIS are able to increase the effectiveness of a road-pricing system in two different ways:

- The motorists can be informed on the road prices by the MIS.

With respect to the first point, the road-pricing system will successfully implement the system optimum only if the price is correctly assessed. As argued in Emmerink, Nijkamp and Rietveld (1994), the theoretically correct road price should be based on future (and therefore predicted) levels of traffic flows, rather than on prevailing ones, the implication being that a device is needed to infer future traffic flows from current ones. In order to do so, data on historic and prevailing levels of congestion should be collected. If MIS are implemented in the transport network additionally to a road-pricing scheme, then the correct prices can be inferred from the data provided by the MIS directly. To implement MIS successfully, traffic data on the current (and even better on the future) traffic situation should be known at all times. Hence, a synergy effect with respect to information on the traffic situation will arise.

With respect to the second point: at least as important as a proper price assessment is the dissemination of the information on the different prices of alternative modes, routes and departure times. Otherwise, the intended behavioural responses might not take place at all, even though the correct pricing incentive to change the individual's trip decision is present. MIS have the ability to act as an interface between the road-pricing scheme and the users' decisions.

Recent research by Verhoef, Emmerink, Nijkamp and Rietveld (1994) has shown that it is not essential to apply a fluctuating pricing scheme in order to reach the system optimum. A combination of a fixed pricing scheme and MIS can be shown to be almost as efficient as the first-best fluctuating pricing scheme.

In addition to the efficiency improvement of a combined road-pricing scheme and MIS, the simultaneous implementation of these technologies will lead to synergy
effects on the cost side. A similar kind of technological roadside infrastructure is needed for both. Furthermore, the devices in the vehicles might be easily transformed to multi-purpose ones: information collecting, information providing and road-pricing charging devices. The scale of these synergy effects is yet uncertain and depends on the kind of road-pricing scheme and MIS implemented. For instance, a simple pricing scheme, such as cordon-pricing, will render only relatively small synergetic effects. For most of the synergy effects to occur, both technologies should be equally technically sophisticated.

Public Acceptance
A combined road-pricing scheme and MIS may enhance the public acceptance of road-pricing schemes. On the one hand, drivers may perceive a road-pricing scheme as an instrument that is in the government’s interest (as discussed in Emmerink, Nijkamp and Rietveld (1994), most motorists are worse off under road pricing). On the other hand, MIS may be perceived as an instrument that is in the interest of the motorists. By combining the two, the government may overcome part of the public resistance towards road pricing without forfeiting their objective of using road space as efficiently as possible.

Brett and Estlea (1989) added that by combining MIS with road pricing the problem of additional trip generation – due to the efficiency improvement produced by the MIS – is solved. Latent demand will remain suppressed because of the existence of the road price.

Take-Off
Thus far we have argued that MIS may help the government in directing the traffic flows in the road network towards the system optimum if they are applied in combination with a road-pricing scheme. The road-pricing scheme provides the incentive to follow system optimal routes, while the MIS increases the effectiveness and public acceptance of the road-pricing scheme. In addition, one might argue that MIS may not take-off without a road-pricing scheme. The technology and infrastructure needed to implement MIS is rather costly and may not be justified by the benefits obtainable from MIS itself, particularly since these are still very uncertain. The fact that the same technology may be used for both a road-pricing scheme and MIS and the fact that these may complement each other may be the impetus needed for MIS to take-off.

Difficulties of a Combined System
Implementing a road-pricing scheme or MIS separately is a difficult task and involves many disciplines such as engineering, economics, behavioural sciences etc. One can imagine that the combined implementation of these technologies is an even greater effort. In this section we will discuss the main difficulties of doing so.

Standardization
One of the most crucial issues in implementing technologies on a large scale is standardization. This is of major importance for two reasons. Firstly, certain standards should be used to ensure that the two technologies use the same infrastructure in order to achieve the synergy effects mentioned above. Secondly, from a practical perspective, it is important that the same standards apply to different countries and regions within countries. Otherwise, great difficulties for cross regional and international transport flows will arise. These might then frustrate the system optimal objective of the policy. Consequently, these technologies should be introduced at a large scale, for instance, within the European Community. Research addressing the possibilities of implementing RTI is currently carried out within the EU DRIVE II (and forthcoming EU DRIVE III) programme. Within DRIVE II, standardization is an
important issue. A typical example of difficulties with standardization within Europe is the high-speed railway systems. Different technologies are used in Germany and France. Moreover, a high-speed train connects France via the Channel Tunnel with Great Britain. In Great Britain however, an 'ordinary' train is bringing passengers down to London (Nijkamp, Vleugel and Rienstra, 1994).

Despite the good intention of these research programmes, the final decision whether and where to go ahead with these technologies is a political one, dominated by national interests. Therefore, the desired large-scale implementation may be an illusion, endangering the synergy effects being achieved in practice.

**Non-Exclusive (Road Pricing) vs. Exclusive (Motorist Information System)**

In the previous section it was argued that a road-pricing scheme and MIS may be viewed as complementary: either one is able to improve the other's efficiency. However, in one respect, these two systems do not fit together perfectly. A road-pricing scheme is non-exclusive, i.e. everyone will be faced with the system; in theory no one should be excluded from paying the road price. Conversely, MIS are a technology that can be exploited on a voluntary base. There is no reason for a compulsory exploitation of MIS. However, when these technologies are applied simultaneously, greater pressure is put on the capabilities of MIS, because of the high levels of market penetration. Recent research (see page 240) has suggested that high quality information is of great importance at high levels of market penetration. Low quality information at high levels of market penetration will endanger the network-wide performance of MIS. Confronted with a malfunctioning system that is passing unreliable or incorrect information, users will quickly lose confidence and not comply with guidance advice.

**Fluctuating Road Price**

We have argued that a combined implementation of a road-pricing scheme and MIS may enhance the effectiveness of both, one of the arguments being that the road price can be assessed properly and according to the current situation in the road network. However, it is questionable whether a road-pricing scheme needs a price that is so strongly dependent on the current traffic flows and levels of congestion. In the first instance, an overly flexible pricing scheme might be hard to understand for the motorists affected by the scheme and therefore may not produce the behavioural adaptations wanted. Brett and Estlea (1989) argue that the simplicity of the pricing scheme is of crucial importance. Secondly, such a pricing scheme might be opposed on fairness grounds. It is unfair to charge a motorist who is faced with a non-recurrent congestion delay (e.g. a traffic accident) when the motorist did not know of the existence of the traffic accident. Even more important, for these motorists it is too late to change to an alternative (route, departure time or mode) and therefore charging them does not alter the traffic situation in the first place. By using simple pricing schemes, such as cordon-pricing, and simple pricing structures these problems may be avoided. These problems may also be avoided if the road price is based on predictions rather than on current levels of congestion (Emmerink, Nijkamp and Rietveld, 1994). Fortunately, Verhoef, Emmerink, Nijkamp and Rietveld (1994) have shown that a fixed (and thus perfectly transparent) pricing scheme – with road prices based (essentially) on expected levels of congestion – in combination with information provision is almost as efficient as a fluctuating pricing scheme.

**Conflict of Interest**

The automotive and telematics equipment producing industry has a key interest in the further development and introduction of MIS. For firms in this sector a combination
of road pricing and MIS may be risky, because the expected acceptance of road pricing among car users is low. A combination of MIS (with a positive image among car drivers) and road pricing (with a negative image) may endanger the acceptability of the product involved, even when synergy effects would occur.

Concluding Comments
Both road-pricing schemes and MIS are useful instruments in resolving part of the congestion problem. They both have strong and weak points. Road pricing is in theory the first-best solution to the problem of transport externalities. Its weak points are particularly the public (and political) aversion mainly due to its redistributional effects. Further, road pricing might have undesired impacts on land-use patterns (the relative productivity of different regions may be affected) and might provide the government with perverse incentives to raise revenues. MIS are essentially a user friendly instrument; no charge is levied, motorists buy the system on a voluntary basis. The price that has to be paid for this user friendliness is that MIS alone are unlikely to be able to resolve the congestion problem. They are a second-best instrument, i.e. they will not direct the traffic flows towards the system optimum.

A combination of a road-pricing scheme and MIS might be useful for both instruments. On the one hand, the addition of a road-pricing scheme to MIS might be viewed as a method to make motorists comply with system optimal routes. Without road-pricing, motorists are most likely to follow user optimal routes. On the other hand, the addition of MIS to a road-pricing scheme improves the efficiency of the road-pricing scheme in two ways:

1. A fluctuating road-pricing scheme need no longer be used (Verhoef, Emmerink, Nijkamp and Rietveld, 1994).

2. The motorists can be properly informed on the prevailing prices so that the intended behavioural responses can take place. Moreover, a simultaneous implementation will most likely lead to synergy effects on the cost side. Finally, the public acceptance of a road-pricing scheme may be raised by jointly implementing these technologies.

The reservations that still exist today among the public in many countries concerning road pricing will probably preclude large-scale introduction at a national or international level. More probable is a – not necessarily high-tech – introduction at particular links or in certain cities.

When these modest starts prove successful a more comprehensive introduction of road-pricing schemes becomes feasible. It seems only at this stage that the synergistic benefits of joint introduction of MIS and road pricing become relevant. At that time MIS will have developed into a mature technology that is ordinarily supplied in cars. Trying to link road pricing and MIS before MIS has reached this stage of development adds a risk to road-pricing schemes and may well retard its introduction.

NOTES
1. The material presented in this section is based on a recent review paper by Emmerink, Nijkamp and Rietveld (1994). See this paper for relevant references.

2. Here, we assume that all the motorists are faced with the road price. In practical applications this may, however, not be the case. For instance, in the Hong Kong pricing scheme taxi drivers were excluded from paying the congestion price (Borins, 1988).

REFERENCES
Dynamic network models and driver information systems. Transportation Research, 25A(5), pp.251-266.


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