



A sense of proportion

Continuous versus discrete pricing

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Traditional approach to tolling using traditional technique



Traditional approach to tolling using modern technique



A modern approach (such as the TIP system) outmodes electronic toll gates

The phrase 'going Dutch' has come to mean 'paying for your share'. When applied to electronic toll collection it opens up a whole new can of worms. However, the fairness and effectiveness of proportionate pricing may prove to be a decisive factor in the public's acceptance of ERP

Electronic traffic fee collection, which includes electronic toll collection (ETC), is gaining importance as an application for traffic information systems. The idea of proportionate pricing is also gaining favour. This involves making each user pay an amount based on their actual share of something, instead of simply distributing costs over the members of a large group (such as vehicle owners or taxpayers) irrespective of each individual's actual share.

The three main goals of traffic tolling are: financing infrastructure (road pricing), reducing congestion and reducing pollution. Proportionate tolling is a particularly effective tool for combating congestion and pollution, because an individual's behaviour is

best influenced when faced with the consequences of their own actions. In the case of traffic, this means an individual is confronted financially with the consequences of their choices concerning, for example, the means, time, speed and route of travel.

Continuous and discrete pricing

We can distinguish two main categories of pricing – discrete and continuous.

In the case of the former, the amount due is determined by gauging at (usually a few) discrete points in time. Discrete pricing – or tolling – can be further divided into open tolling, where there is only one relevant point in time (say, when passing a toll booth), and closed tolling, where there are two (when entering and exiting a system or area,

"Would you like to share one bill?"

"No!" "Yes!"

"No!" "No!"



'Dutch Treat' is a notorious example of proportionate pricing

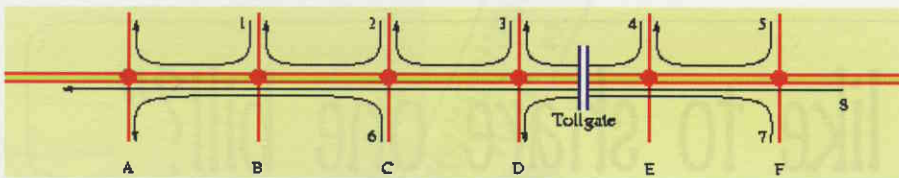


Figure 1: Positioning one toll gate on a congested part of a highway

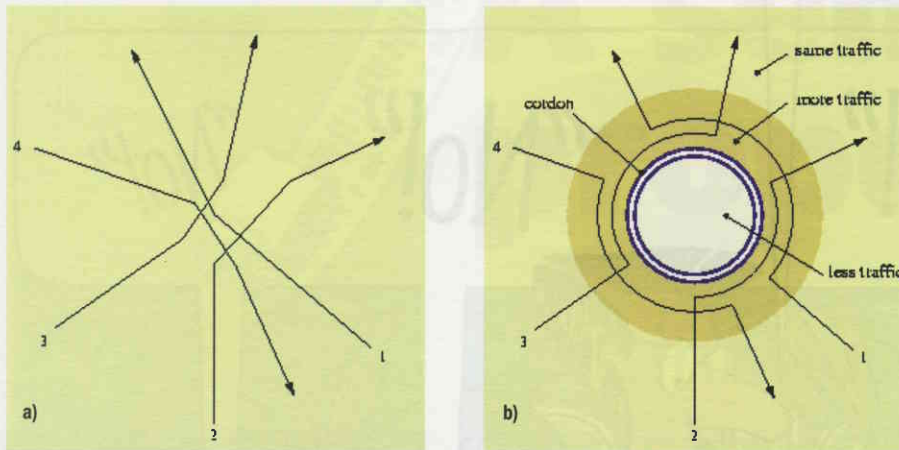


Figure 2: (a) before (b) after. The effect of a cordon in general is that traffic inside decreases while that outside increases

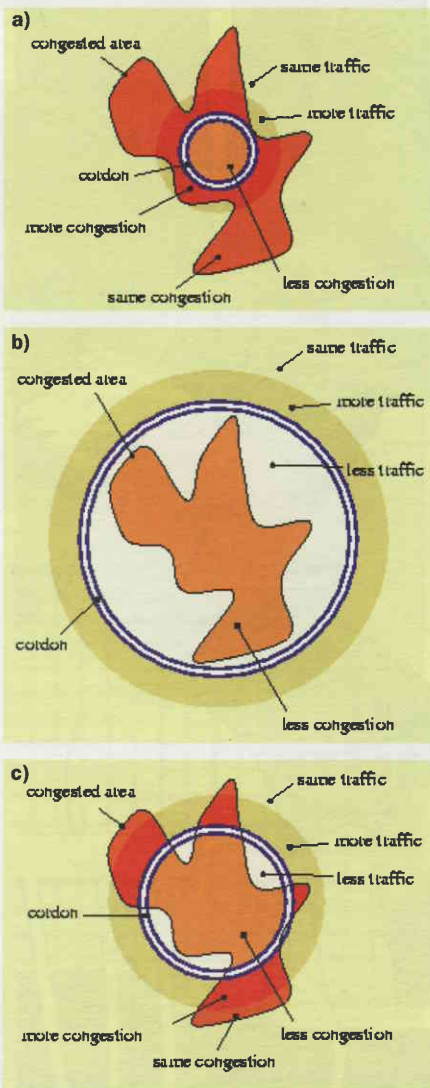


Figure 3: (a) a tight cordon, (b) a wide cordon, (c) an intermediate cordon. Schematic representation of the three possible types of situation

for instance). Within a closed tolling system, behaviour between these two moments is irrelevant: for example, a vehicle entering a car park will be charged only for the time spent within the facility, not for whether it is idle or moving throughout that time.

Continuous pricing sees that each user is charged for their actual behaviour within an area or system by gauging continuously. Relevant behaviour can include, for instance, actual distances travelled and pollution caused (both emissions and noise). So, with continuous tolling there are infinitely many relevant points in time. It offers, therefore, a more finely tuned approach and represents the best possible answer for proportionate pricing. Examples of continuous tolls are a 'kilometre tax' on distance travelled and charging insurance premiums on a per-kilometre basis.

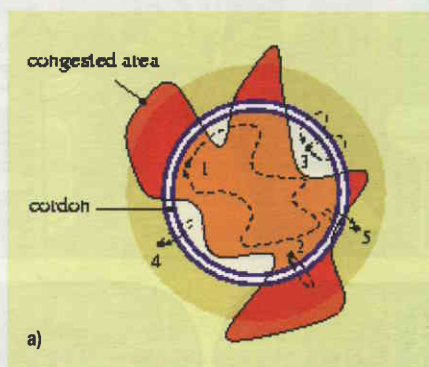


Figure 4: (a) a typical cordon (b) a perfect cordon. Some resultant unfairness – users of types 2, 3 and 4 usually occur, as perfect cordons are practically impossible

Going Dutch?

In comparison with discrete tolling, continuous tolling stands out as being (in many applications):

- More versatile (it is better suited to pollution and congestion pricing);
- More effective (it affects all mobility);
- Fairer (it is better suited to proportionate pricing);
- Efficient (the need for expensive toll gates is reduced or even eliminated).

Discrete tolling – the drawbacks

Discrete tolling has the following disadvantages:

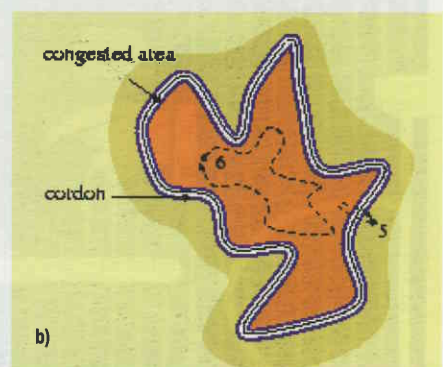
- It requires many toll gates, while electronic toll gates are expensive;
- It is often difficult to position toll gates well;
- It often creates situations that are felt to be unfair by users;
- It is unsuitable for pollution pricing;
- It influences spatial (that is, town and country) planning.

Below we will give two examples illustrating most of these drawbacks, in particular for the case of open tolling in the context of congestion pricing.

Example 1: Positioning a toll gate

Figure 1 shows a highway that suffers from congestion between junctions A and F. If we were set the task of reducing congestion using only one toll gate, we might (for example) place it between junctions D and E, as shown.

This creates inequities. Users 1 to 5 travel along one section of the road but only user 4 has to pay. Users 1, 2, 3 and 5 do not. Even worse, user 6 will not be tolled despite contributing to congestion twice as much as user 4. Users 7 and 8 pay the same amount as user 4 but their contributions to congestion are, respectively, twice and five times greater.



Effectiveness is also a problem as a toll gate can only reduce traffic that passes through it. In Figure 1, users 4, 7 and 8 will be discouraged from using this highway but the others will not. On the contrary, this road will become even more attractive to non-paying users, at least for a short time after the toll gate becomes operational. Therefore, we can expect that the section of road between D and E will become less congested, while congestion levels elsewhere will remain much the same.

Obviously, choosing another location for the toll gate is not a solution. However, placing a toll gate on each section of road would be expensive and a closed tolling system even more so.

Example 2: Positioning a cordon

What if we use a cordon of toll gates? If traffic can only enter an area after paying a substantial fee, it will avoid that area. In particular, through traffic will try to find a reasonable alternative route that does not cross the cordon. The effect will be that the amount of traffic within the tolled area will be reduced and traffic in surrounding areas will increase,

as shown in Figures 2a

and 2b. Also, environmental pollution may increase because of the resultant detours taken by drivers.

We will now consider the three types of situation that can arise when using cordons for congestion pricing. In the first, the cor-

doron is fully within the congested area. With such a 'tight' cordon, the already congested area just outside the cordon will suffer further (Figure 3a).

In the second type of situation the cordon is 'wide', or fully outside the congested area (Figure 3b). Note that the following is true in general: the wider the cordon chosen, the higher the percentage of non-paying users of the congested area will be, as more of the traffic using the congested area will not have to cross the cordon. So, a wide cordon may imply a percentage of non-paying users high enough to result in problems with effectiveness as explained below.

Suppose by way of example that 70 per cent of the traffic using at least part of the congested area will not have to cross the cordon or will remain toll-free otherwise. Also suppose that a 15 per cent reduction of traffic within the congested area is needed to reduce the level of congestion sufficiently. Then the toll for crossing the cordon would need to be high enough to deter half the traffic

"Perfect cordons are unlikely as the number of toll gates needs to be minimised, while the cordon must remain fully closed to prevent drivers 'rat running' along smaller roads"

formerly using the congested area AND crossing the cordon. Actually, that figure would be more than half, as more non-paying traffic will be attracted as soon as the congestion decreases. If there is a potential for attracting at least 15 per cent of extra non-paying traffic, then even tolls of an absurdly high level will not reduce congestion sufficiently for there will be enough non-paying traffic to ensure congestion in any case.

If we replace the figure of 70 per cent with 55 per cent, the cordon has to deter more than a third of the relevant traffic and will therefore be ineffective, regardless of the toll level, if there is a potential for 30 per cent extra toll-free traffic using the congested area.

The third possible situation is a cordon being neither tight nor wide but 'intermediate', as illustrated by Figure 3c. In this more typical situation the problems related to tight and wide cordons may occur all at the same time. Note that the increase in traffic resulting from economic growth will usually turn an initially wide cordon into an intermediate one.

And more ...

These examples clearly illustrate the problems of using discrete tolling to reduce congestion. We have not yet even addressed the inequities resulting from a cordon but it is clear that they are there. In Figure 4a users of type 1 (delivery

drivers, for example) contribute amply to the congestion without paying, while users of types 2 to 5 (residents on the fringes of the cordon, for example), would have to pay for very short trips that cross the cordon. Note that users of types 3 and 4 have to pay even though they do not enter the congested area at all. The existence of users of types 2 to 4 is a direct consequence of not having a

perfect cordon, as shown in Figure 4b. In practice, perfect cordons are unlikely as the number of toll gates needs to be minimised, while the cordon must remain fully closed to prevent drivers 'rat running' along smaller roads. The latter would be bad for both safety and environmental reasons.

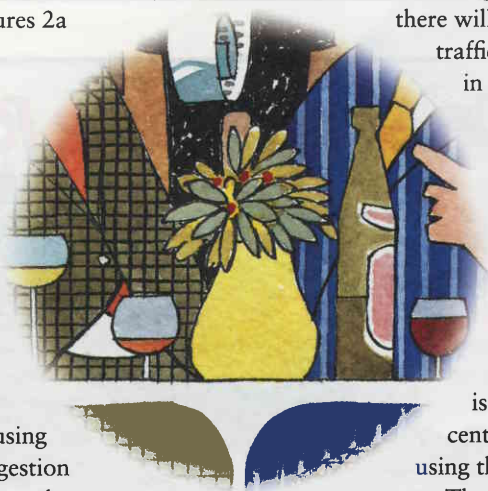
In all examples above we have assumed more or less explicitly that tolls only have to be paid when passing through a toll gate in one direction. Of course, one could also – or instead – charge for passing in the opposite direction. The resulting differences for the analyses are left to the reader.

Finally, it is worth mentioning the substantial risk that discrete pricing will influence spatial planning in an undesirable way. For example, many companies may try to locate themselves on a particular side of the toll gate or cordon to avoid being forced to reimburse paid tolls to employees in order to remain competitive with other employers already located there. Such hard-to-predict effects on spatial planning complicate the positioning of toll gates and cordons even more.

We conclude that it is a difficult, if not hopeless task to position a toll gate or cordon well enough to achieve sufficient effectiveness and fairness. Our overall conclusion is that, in general, discrete tolling (that is, using tollgates) is not a good approach for implementing congestion pricing.

Continuous tolling – the virtues

We have shown that continuous tolling is better suited to congestion pricing than



discrete tolling. It can also be used to price pollution. A kilometre toll could have a price per kilometre based not only on the class of vehicle being driven but also on the style of driving, penalising aggressive motoring that causes more pollution (see the following article, 'Tolling TIPs'). Discrete tolling is not suitable for pollution pricing, as toll gates encourage drivers to make detours. Continuous tolling can also be used for road pricing in the strictest sense.

Continuous tolling may be implemented more cheaply than discrete tolling due to the lack of a need for toll gates. It is also more effective and more fair, as it affects all mobility and, as stated earlier, is the ultimate form of proportionate pricing, which is important not only from the point of view of effectiveness but also public acceptance of traffic pricing.

To illustrate the importance of fairness and effectiveness, consider the Netherlands' Rekeningrijden Project. This went down the path of introducing congestion pricing using open tolling based on a cordon setup. Public and business opposition has been and still is very strong because of perceived inequities, expected ineffectiveness and the

high level of investment required. As a result, Rekeningrijden has recently been downgraded to an experiment with only one city (from the original four) and no city is willing to volunteer.

Popular opinion has it that Rekeningrijden is dying and that the only real problem left is finding an elegant way out for the politicians and other people involved in the project.

While more than 75 per cent of the Netherlands' population is against this cordon approach, there is a general belief

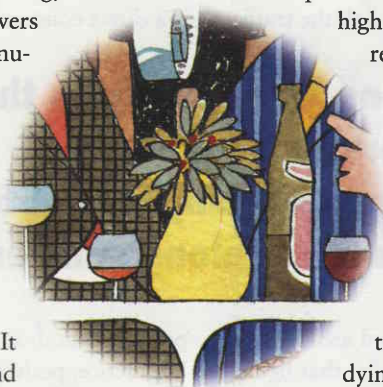
that an ample majority would accept a kilometre tax to replace the current licence tax. Apart from the crucial point of acceptance, a kilometre tax would also bring all the advantages listed above. In any case, it seems to offer Rekeningrijden its only reasonable chance of survival.

This example taken from real life increases our confidence that proportionate pricing in general, and continuous pricing in particular, are indispensable.

Summary

For many applications continuous pricing is both preferable and superior to discrete pricing, being more versatile, effective, fair and cheap. All this leads us to the conclusion that general-purpose traffic information systems should – as a matter of course – be able to support continuous traffic pricing. ■

The author thanks Michel Oey for his help in producing the figures and for his comments. An extended version of this article can be found at: www.cs.vu.nl/~wiebren



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