Tolling TIPs

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Supporting advanced pricing

Continuous and proportionate pricing are detailed in an accompanying article, 'A sense of proportion' elsewhere in this issue. But what of traffic information systems that can support them? Surely someone holds a solution that makes them not only digestible, but palatable as well ...

The ideal traffic information system (TIS) should be able to support road, congestion and pollution pricing. It should be suitable for proportionate pricing in general and continuous pricing in particular and, as if that isn't enough, it should be built to evolve and provide for sufficient levels of fraud resistance and privacy protection.

In this article we will look at some of the above features in more detail and in relation to TIP, a system that meets all the above requirements.

Proportionate traffic pricing

A fuller explanation of the different types of traffic pricing to be supported has already been given in the previous article 'A Sense of Proportion'. In particular, the when applied to congestion and pollution pricing.

The ability to evolve

A TIS must be flexible and allow for gradual development. It must be possible to introduce the TIS to a small subset of vehicles in the first instance and then be able to enlarge that subset over time. It should also be possible to introduce a simpler version of the TIS which can then be refined and extended. Such refinements and extensions cannot be limited to a single application (such as traffic pricing); a TIS must be able to accept new applications and integrate them if it is to be durable.

Fraud resistance and privacy

Fraud resistance and privacy protection

The TIP system

TIP is an acronym derived from Traffic Information and Pricing. TIP actually encompasses a whole class of systems with certain characteristics. Crucially, it meets all the criteria listed above.

Proportionate pricing

The TIP system is able to support road, congestion and pollution pricing. For each of these it allows both discrete and continuous pricing. So, it can be used to implement electronic collection of traffic fees, such as insurance premiums and/or a kilometre tax, where the fee for each distance unit can be related to (for example):

- Time of day, date, location and/or traffic density;
- Vehicle type (manufacturer, model, year, transmission type, engine type);
- Vehicle speed, acceleration, gear chosen, and so on.
- Fuel type and/or consumption;
- Environmental impact (emission, noise).

That congestion and pollution pricing can be implemented follows from the first point and the next three points, respectively. The third point is related to driving style and behaviour, which both influence fuel consumption and pollution. The fifth point describes possible types of pollution pricing. Note that TIP does not require toll gates for such continuous pricing.
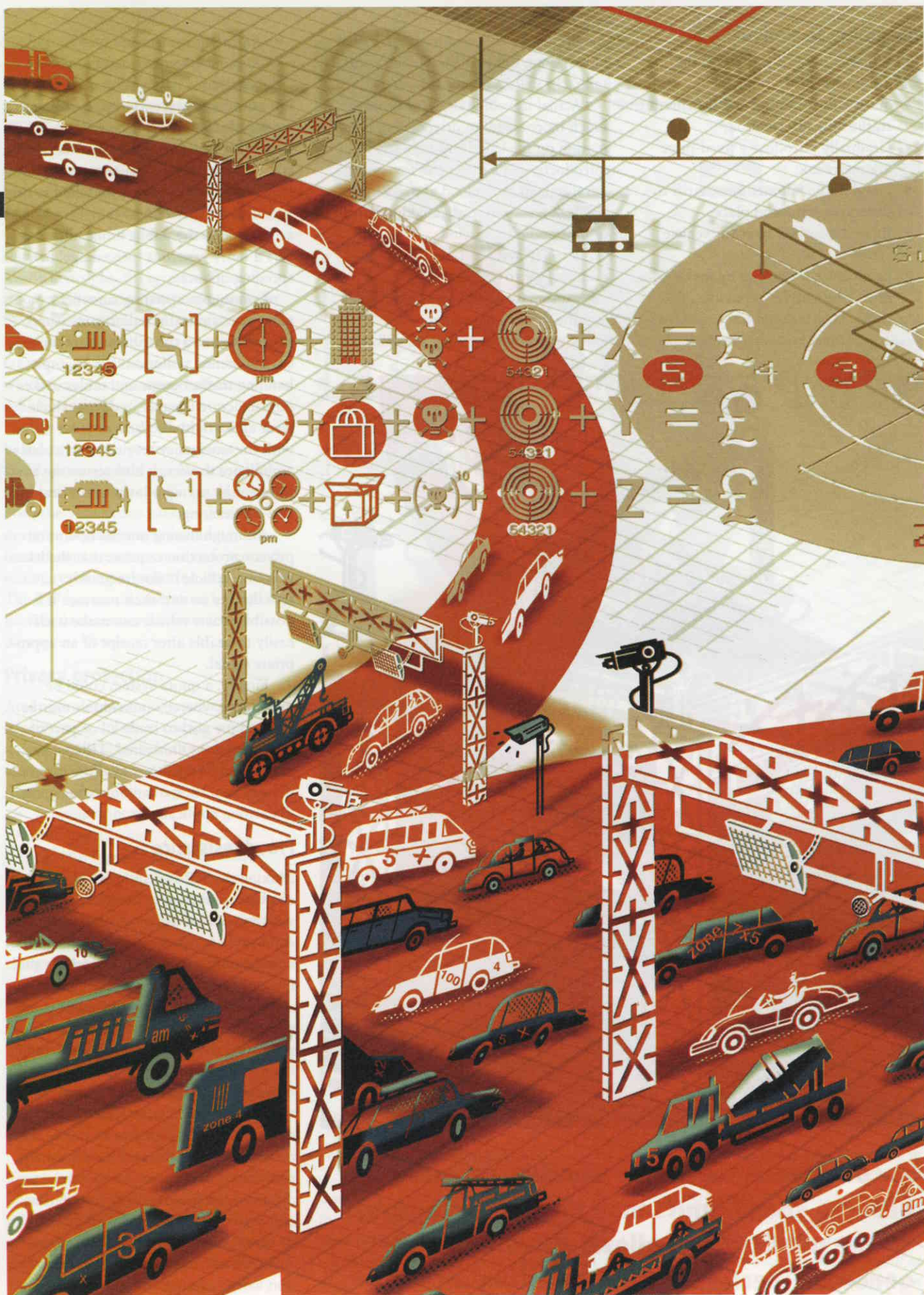
"Proportionate pricing is expected to grow in importance because of its inherent fairness (and, therefore, public acceptance) and its effectiveness"

ideal TIS should support pricing – or tolling – in a form that actually reflects the use made by individuals of the road system. This, proportionate pricing, is expected to grow in importance because of its inherent fairness (and, therefore, public acceptance) and its effectiveness

are slightly at odds with each other. For a road pricing system to be resistant to fraud, a certain level of verification is necessary and this involves identification of sorts. Nevertheless, it is a solvable problem, as is demonstrated by the TIP system.

The ability to evolve

TIP systems could be evolved in the following way:

- Start with collecting and distributing traffic flow information;
- Gradually introduce a fixed-price kilometre tax;
- Develop the kilometre tax tariff to depend on time and place;
- Extend it further to cover vehicle type;
- Complete the exercise by making the tariff cover driver behaviour.

The traffic flow information can encompass travel times currently being realised. As this can be collected and distributed in real time, information on delays due to tailbacks will be highly accurate.

Actual travelling or delay times are much more useful to drivers than information on the lengths of tailbacks. The introduction of a kilometre tax and its development as detailed above would result in a very sophisticated implementation of pollution pricing.

The TIP system could be extended even further to include:

- Automatic speeding prevention at the driver's request;
- Continuous speeding surveillance;
- Anti-theft measures;
- A quota system for usage rights;
- Negotiable usage rights.

For automatic prevention of speeding to work, vehicles would need to be supplied with local speed limit information which could be used by the cruise control system. A continuous watch on whether drivers observe speed limits may become acceptable to the public if one allows drivers a fairly generous 'percentage' of speeding offences.

Continuous speeding surveillance makes certain traffic calming measures superfluous and contributes to reducing environmental pollution. For example, banning traffic bumps and tables makes infrastructure cheaper, reduces vehicle wear and would also be a popular move with the emergency services, particularly ambulance drivers. It also serves the environment by saving a lot of extra braking and accelerating.

Although during normal operation privacy protection requires that the location of a vehicle is not frequently revealed, as an anti-theft measure it is possible that a vehicle can make itself easily traceable after receipt of an appropriate signal.

Finally, a quota system could be introduced whereby individuals may be allowed (or not) to trade all or part of their quota. As illustrated, TIP systems can indeed be flexible and allow for gradual incorporation of and/or refinements to existing applications.

Fraud resistance

Making the TIP system resistant to fraud can be approached in two different ways: with or without using so-called agents. An agent is a representative of the TIS and the only component in a vehicle that must be tamper-free. It can consist of a software/fraud-resistant processor combination that pays particular attention to protecting the memory locations containing its software, cryptographic keys and other crucial information.

An agent will continuously monitor data about the vehicle (for example, the number of revolutions of the driveshaft), perform computations (for example, to determine its speed) and at certain times report to the rest of the TIS (for example, its speed, distance travelled and so on). An agent can also do part of the verification work required.

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In the setup without agents, the information-handling equipment in a vehicle does not have to be protected at all and will simply supply raw information to the TIS. Then all verification of the accuracy of information supplied will be performed remotely. Either way, the accuracy of information supplied by the vehicle will be checked using random sampling in order to build fraud resistance.

At first sight, the setup without a fraud-resistant component may seem to be the most attractive. However, the setup with agents has important advantages too, such as requiring less bandwidth for communication between vehicles and TIS.

It is to be expected that attempts will be made by some parties to commit fraud, particularly if the TIS is used for applications such as traffic pricing. However, the verification process detects all deviations and offences including unintended ones – engine wear and incorrect tuning resulting in pollution, for instance. The TIP system can therefore be used to prevent unnecessary environmental damage.

Privacy protection

An important aspect of protecting privacy is preventing unlawful tracing of individual, uniquely identifiable people and/or vehicles. TIP achieves this by using at least one of the following:

- Semi-identifications;
- Agents;
- Certain types of intermediaries.

Semi-identifications allow privacy-friendly tracking of vehicles for a limited distance. They can be used, for example, to determine an individual vehicle's travelling time between two points that are sufficiently close together. Applications include trajectory speed traps, the determination of delays caused by tailbacks, and traffic flow control.

For semi-identification, no fully unique feature of a vehicle, its owner or driver need be revealed and privacy is assured.

Agents can be used to collect and verify information in such a way that the use of privacy-threatening, uniquely identifying information can be kept to a bare minimum. Although the use of agents and/or semi-identifications can suffice, TIP has a third mechanism for privacy
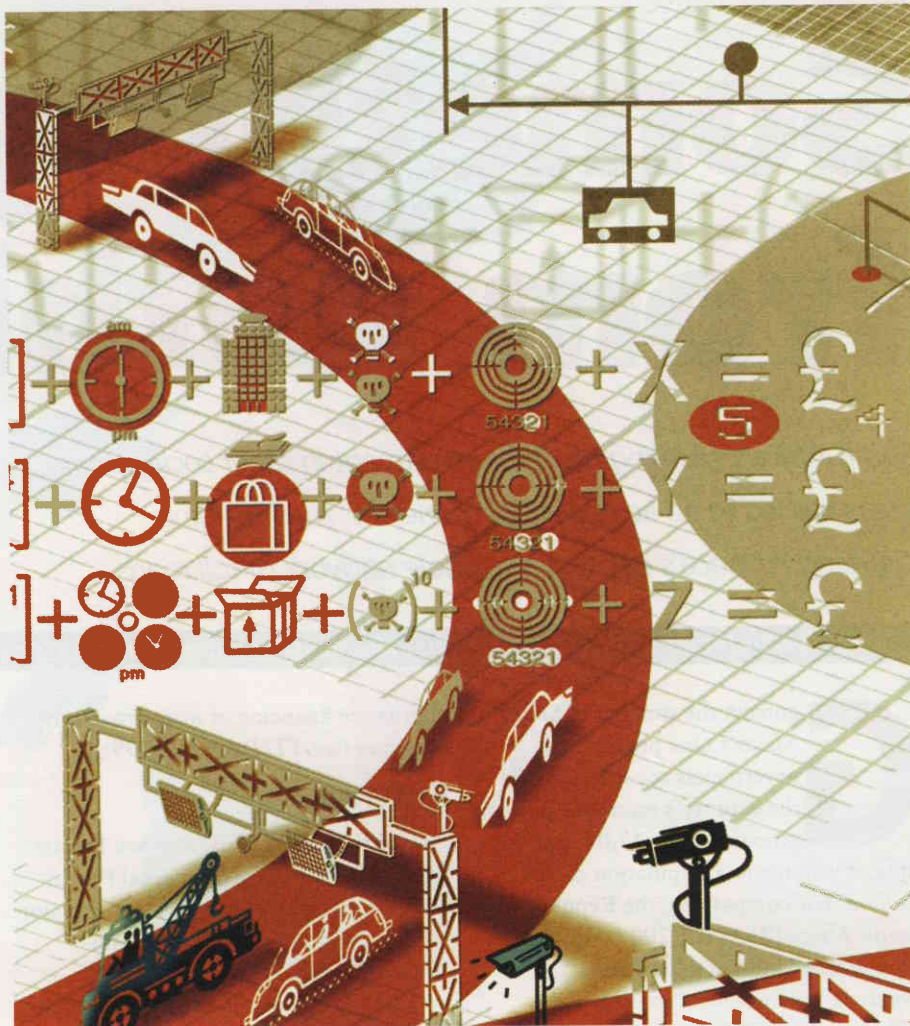
protection – the use of intermediaries.

This mechanism is effective even if the data collected from a vehicle does contain identifiable material.

TIP versus other systems

The TIP system is unique with respect to the number of aspects about which reliable information can be collected. These include distance travelled, fuel consumed, noise produced and other environmental pollution caused.

The TIP system seems also to be unique in being able to provide a high level of fraud resistance and privacy protection while offering many forms of traffic pricing, including continuous pricing.

All other systems that are able to support continuous pricing based on distances travelled (such as a kilometre tax), are positioning based. However, these are more expensive because of the need for GPS or electronic mapping equipment. They also offer a lower level of privacy, as the agents required by

positioning systems inherently know all successive vehicle locations. Preventing each and every agent from supplying traces to the outside world is difficult, if not impossible, as covert channels could be used. As the TIP system is not positioning based, its agents do not need to know a vehicle's location … and it is easy to prevent agents from distributing information they do not have. ∎