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PRICING METHODS

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CONTENTS

PRICING METHODS

1.DEFINING ROAD PRICING

In order to consider the range of pricing methods available, it is first necessary to choose a definition for road pricing. The term "road pricing" has been criticised as an inaccurate description of systems which is applied to (Thompson, 1990) and there is some inconsistency regarding the extent of charging policies which are considered to be included. A liberal definition could cover any fiscal form of traffic restraint, affecting the mode, time, route, destination of frequency of journeys. In this case road pricing already exists worldwide through taxes imposed upon the purchase and licensing of vehicles and through fuel taxation. The extension of conventional taxation arrangements has been used as part of road pricing strategies in both Hong Kong and Singapore (Dawson and Brown, 1985; LPAC, 1991). However, the essence of most road pricing work has been to replace and supplement these existing charges, which do not discriminate by time, location or amount of vehicle use, with charging structures which are directly related to these issues. For this reason the descriptions road-use pricing, congestion pricing and road user charging are sometimes preferred, and some recent texts have attempted to impose a narrower definition for road pricing, in which only charging systems relating directly to the time and distance travelled are included (CIT, 1992). For the purposes of this review it is best to retain the conventional term of road pricing and apply the broadest definition.

2. THE OBJECTIVES OF ROAD PRICING

The practical objectives of road pricing have been developed beyond the economic principles of making good the gap between marginal personal cost and marginal social cost and have been well documented (May, 1986; May, 1992). The relative importance of each objective for individual schemes, as perceived by those responsible for planning, plays an important role in system design and should be considered when assessing the effectiveness of proposed and operating road pricing schemes. The five principal categories for objectives have been set out below.

2.1 EFFICIENCY

Improving the efficiency of road use relates directly to the pricing principles set out in the economic literature. These economic arguments were the basis of the Smeed Report (Ministry of Transport, 1964). Smeed estimated that at a speed of 21km/h each additional driver on a network imposes time losses upon others equal to his own travel time, and that this rises to time losses double his own travel time at 16km/h (Smeed, 1968). Subsequent work has suggested that this analysis may be too simple, ignoring the effects of queuing (Button and Pearman, 1983) and failing to consider the effects on drivers travelling later in the congested period (Smith and Ghali, 1991). These arguments relate principally to the levels of charges which would be required to secure maximum efficiency and do not detract from the basic concept which would be required to secure maximum efficiency and do not detract from the basic concept that there is a discrepancy between the marginal private cost perceived by the road user and the marginal social cost, the true cost of a journey, which includes the additional costs imposed on other users. In practical terms, improving efficiency on a road network means reducing congestion and is an objective driven as greatly by other economic

and political concerns as by the initial theory. There are also two important qualifications to be made:

a)The resources required to operate a charging system should not exceed the benefits achieved by it.
b)The resources required should include any provisions which are necessary beyond the system boundaries due to transfer effects.

Failure to address these points could result in a net loss to overall efficiency.

2.2 ENVIRONMENTAL PROTECTION

Traditionally, environmental impacts of transport have been viewed as local issues and have focused upon the following concerns:

a) Noise and vibration.
b) Primary pollutants (eg. carbon monoxide).
c) Visual intrusion.
d) Severance.
e) Danger and accidents.

Increasing worldwide environmental concerns have extended these boundaries to include impacts from transport at the regional level, such as secondary pollutants (eg. ozone and acid rain) and at the global level with the contributions of traffic to emissions of carbon dioxide. Charging has been identified as a means of attempting to reduce all these impacts, but the type of charging system appropriate for tackling local impacts may be very different to those required at a regional and global level. the concept of a "carbon tax", administered through fuel prices, has been the centre of recent debate (Pearce et al, 1989). This would attempt to produce the significant overall reduction in fuel use, independent of time and location, required to address the regional and global pollution issues. By contrast reduction of the environmental impacts of transport at the local level would require measures to reduce traffic levels at specific sensitive locations, during particular times of day and may wish to target individual classes of user, such as heavy commercial vehicles. Therefore, a direct change upon vehicle use would be more appropriate. As local impacts are closely related to prevailing levels of congestion, local environmental charges could be levied in the same way as those designed to improve efficiency on the network, with both objectives benefiting from similar time and location specific reductions in traffic.

It has been suggested that there may be areas of incompatibility between the objective of improving efficiency and that of reducing environmental impacts. It is argued that the reductions in traffic necessary to achieve targets for environmental improvement may be greater than those desired to maximise efficiency. This may be addressed by incorporating environmental costs into the calculation of marginal social cost (Button, 1991). In addition, it has been suggested that there may be incompatibility between the local level and regional and global considerations within the environmental objective. A local road pricing scheme may achieve benefits to sensitive locations as a result of transferring environmental impacts, but overall there may be no reduction, or even an increase, in fuel use, if greater distances are travelled by diverted traffic. In practical terms, environmental protection is becoming an increasingly important justification for road pricing policies and may have a crucial role to play in gaining widespread public support.

2.3 URBAN PLANNING

It has been argued that road pricing policies may be beneficial to other urban planning goals by improving accessibility and helping to revitalise urban areas. Traffic growth and congestion has, over time, reduced urban accessibility and, alongside its associated adverse impacts on the local environment, contributed to the decentralisation of industry, commerce and residential sectors away from inner and central city areas. If accessibility is perceived in terms of both cost and travel time (Jones, 1981), it is difficult to predict what the net effect of road pricing charges would be. The greatest impact may derive from a redistribution of accessibility levels by user type, related to journey purpose and socioeconomic group. Land use planning objectives of increased urban investment will depend upon the effects of road pricing measures on accessibility, the local environment and, perhaps most importantly, upon the general image of local transport policy. The fear that this image will be negative and will offset other benefits, exacerbating existing decentralisation trends, has also been expressed. The relevance of these arguments may vary by location, dependent upon general urban planning policy and other specific planning and road pricing objectives. For example, a package of measures incorporating the provision of an alternative public transport option could be designed to increase accessibility across all travel groups and have a very positive effect upon both public and business perceptions of local transport policy if successfully marketed.

2.4 EQUITY

Equity issues are related very closely to those of the urban planning objectives via accessibility. The standard equity objective is to redistribute the transport costs and benefits in a more just manner than under present congested conditions. In practice it is hard to imagine a change to the economic status quo which would not involve both benefits and disbenefits to equity. Suggested improvements to equity as a result of road pricing include (May, 1986):
a)The protection from congestion of those with particular need.
b)A reduction in environmental disbenefits incurred by residents, pedestrians and cyclists.
c)The diversion of unnecessary through traffic away from the urban area.

However, disbenefits may include:
a)Higher costs for low income car users.
b)Relocation of problems.
c)Increased costs to those without an alternative.

It is popular to propose road pricing as a means of redistributing road space more equitably between private cars and road-based public transport and in relation to need, based on values of time. It has also been suggested that any assessment of equity issues should be disaggregated by user type (including non-road users, such as residents), location, income group, journey purpose and need, in order to distinguish significant equity issues affecting particular groups which are offset by more general trends.

2.5 REVENUE GENERATION

Although initially considered to be an unlikely local objective of road pricing (May, 1986), the potential generation of revenue has proved an extremely popular justification in practice, linked to

the need to finance other transport policies. These include other forms of traffic restraint and calming, environmental improvements, new and improved public transport systems and even the improvement and building of roads (Waersted, 1992; Hoven, 1992).

2.6 EVIDENCE OF OBJECTIVES

Evidence of objectives for implemented and proposed road pricing schemes shows considerable variation (LPAC, 1991). The reduction of congestion was the principal concern in both Singapore and Hong Kong, while environmental benefits were the principal focus in Holland and Stockholm. Early work in London relating to supplementary licensing was principally concerned with congestion, but also acknowledged the potential environmental improvements (May, 1975). By contrast, work in Melbourne has identified the financial inequities of existing transport taxation between urban and rural road users as the principle justification for urban road pricing (Howie, 1991). More recent studies have tended to acknowledge the whole range of potential objectives, but revenue has been the driving force behind the Norwegian toll rings and although congestion is the clear focus of the congestion metering system proposed in Cambridge, related proposals to use revenue to develop a new public transport system identify this as a second important objective. A recent study for Edinburgh (May et al, 1992) has proposed road pricing as part of a package of measures designed to achieve a wide range of benefits. The specific role of road pricing within such a policy may be seen as providing revenue to fund other measures and reinforcing incentives for private car users to switch to public transport.

3. CRITERIA FOR THE DESIGN OF ROAD PRICING SYSTEMS

The Smeed Report (Ministry of Transport, 1964) produced a list of criteria for the design of road pricing systems:

1)Charges should be closely related to the amount of use made of roads.
2)It should be possible to vary prices for different areas, times of day, week or year and classes of vehicle.
3)Prices should be stable and readily ascertainable by road users before they embark upon a journey.
4)Payment in advance should be possible although credit facilities may also be permissible.
5)The incidence of the system upon individual road users should be accepted as fair.
6)The method should be simple for road users to understand.
7)Any equipment should possess a high degree of reliability.
8)It should be reasonably free from the possibility of fraud and evasion, both deliberate and unintentional.
9)It should be capable of being applied, if necessary to the whole country and to a vehicle population expected to rise over 30 million.

May (1992) has stressed the validity of these criteria for assessing proposed pricing systems 30 years on, suggesting that (9) may need to be revised to apply to potential international systems and

even greater numbers of vehicles. Three additional criteria are also suggested (Thompson, 1990; Hau, 1992):

10)The system should allow occasional users and visitors to be equipped rapidly at low cost.

11)The charge recording system should be designed both to protect individual users' privacy and to enable them to check the balance in their account and the validity of the charges levied.

12)The system should facilitate integration with other technologies, particularly driver information systems.

4. ALTERNATIVE CHARGING STRUCTURES

Bearing in mind criteria (3), (6), (9) and (11) above and general economic and technological constraints, it is unlikely that a road pricing system which closely reflected the economic theory, requiring the calculation of separate charges for every link in the road network, would be either feasible or desirable. In practice systems which have been proposed, and even more those which have been implemented, are conspicuous by their simplicity. Four principal categories of system can be identified, which are discussed in order of complexity. If a stricter definition for road pricing were applied it could be that only the fourth of these categories would be included, as only time and distance based charges attempt to approximate the economic concept of pricing for individual users.

4.1 EXTENSION OF EXISTING CHARGING AND TAXATION ARRANGEMENTS

This involves the representation of road pricing charges through three conventional taxation systems:

a) Vehicle purchase tax.
b) Vehicle licensing.
c) Fuel tax.

The first two of these attempt to reduce vehicle use by constraining ownership, and have been used in Hong Kong and Singapore. In 1982, purchase tax for new cars was doubled and the annual licence fee trebled in Hong Kong, resulting in a 25% reduction in car ownership during the following twelve months (Dawson and Brown, 1985). In Singapore new car sales have been regulated by a monthly quota, with purchase tax determined by bids. Also, some cars have been licensed at a reduced rate for use only at weekends (LPAC, 1991). The problems with these methods are that they have a low flexibility for discriminating by time and location and are completely unrelated to the amount of road space used (failing criteria (1) and (2) specified by Smeed). Evidence from Hong Kong shows that the impact on car use was negligible in the most congested areas but produced a 19% reduction in the lower income less congested areas. This implies that the remaining car owners were using their vehicles more, that the wrong geographical areas were being targeted and that there may have been serious equity disbenefits to lower income car users.

Administering road pricing charges through fuel tax would be more closely related to the amount of vehicle use, and there is evidence of an elasticity demand with respect to fuel prices in the range -0.1 to -0.5 (Goodwin, 1988). However, it is not possible to discriminate at all by time and location

(criteria (2)) and there is evidence that the wrong trips are targeted, with off-peak and leisure journeys being hit first (Atkinson and Lewis, 1975). In addition, in recent international discussions, a carbon tax has been greeted with resistance by politicians. The potential of fuel taxation to tackle the regional and global environmental impacts of transport, remains, but it seems to be rather less effective at the local level and would have economic and political implications beyond those expected from other road pricing methods.

4.2 SUPPLEMENTARY LICENSING

Supplementary licensing may be considered as an extension of administering road pricing charges through conventional vehicle licences, attempting to add flexibility for targeting specific times and locations. The system involves the purchase of an additional licence to travel within a particular area defined by a specified cordon. Charge levels can be varied by time of day, direction of movement across the cordon and type of vehicle. The cordon may be a single perimeter boundary or a series of cells. Such a system was proposed for London (GLC, 1974) and has operated in Singapore since 1975. The Singapore system has required the purchase of licences on a daily or monthly basis to be displayed in the vehicle windscreen, allowing access to the centre during the morning peak period. Enforcement has been manual, requiring comprehensive staffing on the cordon, but an electronic alternative would be possible and is being considered to allow a more complex system to be introduced covering the national road network (Holland and Watson, 1978; LPAC, 1991). The main criticism of supplementary licensing is that it may not sufficiently satisfy criteria (1), relating charges to amount of road use, although a more complex series of cordons or cells may help to address this.

4.3 CORDON TOLLS

Cordon tolls are similar in principle to supplementary licensing, with a charge being levied to permit travel within a specified area defined by a single or series of boundaries. The main distinction is that the charge incurred is directly related to the number of boundary crossings, which may help to address criteria (1). As for supplementary licensing, charges may be varied by time of day, direction of travel and vehicle type. Tolls may provide greater flexibility for applying the charge structure to one-off or unpredictable journeys, with the purchase of access being instant rather than pre-planned (criteria (10)), although a sophisticated electronic system may be able to allow instant purchase of a licence. Cordon toll systems operate in three Norwegian cities and a pilot project has been conducted in Hong Kong. In Norway, a single toll cordon was installed around the city centre of Bergen in 1986 and similar systems have since been added in Oslo (1990) and Trondheim (1991). As the main objective has been revenue collection to fund other transport projects, no attempts have been made to apply a more complex cordon arrangement and tolls have been charged throughout the day at a uniform rate. A limited examination of the effects upon traffic in Oslo has revealed only a very small reduction in volumes, principally outside peak hours (Waersted, 1992; Hoven, 1992). A wide range of technology levels have been used during toll collection, from manual booths to electronic tags, with cordon crossing points cointrolled by individual toll stations on local roads and major plazas on the heavily trafficked arteries.

In Hong Kong, a much more complex system was envisaged. It was proposed that all vehicles would be fitted with electronic number plates which would be identified by loops buried in the carriageway. All vehicles would possess an account to be billed on a monthly basis. A series of charging regimes were considered, of which the most complex involved the adoption of 13 different cells, requiring 185 charging points, with eight separate charge levels per day (Catling and Harbord,

1985; Harrison et al, 1986). Despite the technical success achieved in the pilot project, the Hong Kong system was rejected, partly because of the invasion of privacy implied by vehicle identification (criteria (11)).

Even cordon tolls have been criticised for failing to meet criteria (1) on the grounds that they do not discriminate by the level of congestion on the network (Oldridge, 1990), levying the same charge whatever the prevailing conditions and additional delays resulting from a trip. Also, there are implications related to levying the whole charge for travelling within an area at a single cordon point rather than on a continuous basis. Trips which terminate just inside a charge point will pay the same as those travelling extensively within the cordon and trips with origins and/or destinations just outside a charge area will experience a disproportionate incentive to change their travel decisions.

These "boundary effects" raise concerns regarding the ability of cordon tolls to satisfy criteria (1) and may lead to perceptions of unfairness (criteria (5)).

Norwegian experience has identified the need to retain manual toll booths in a population where some vehicles would be unequipped, if one-off and occasional users are to be catered for (criteria (10)). The physical space required to accommodate toll booths would constrain the complexity of toll cordons which would be feasible in many urban situations. By contrast, a fully electronic system requires no additional space, but may need special provisions to satisfy criteria (10).

4.4 TIME, DISTANCE AND CONGESTION BASED CHARGING

Critics of the above three road pricing methods tend to favour systems where charges are directly related to the time spent travelling and/or the distance covered, which can be regarded as immediately addressing criteria (1) and reflecting levels of congestion. Two such systems are currently being considered in the UK:
a)The TIMEZONE system in Richmond, London.
b)Congestion metering in Cambridge.

TIMEZONE levies a charge based on the time spent travelling in a specified area. Charge rates can be varied by time of day, user class and across a series of different zones (EASAMS, 1991). Congestion metering involves the recording of time taken and distance covered for each vehicle on a rolling basis, with a charge only being levied when a specified threshold is exceeded (Oldridge, 1990). Both these systems require the technology of an in-vehicle unit to calculate charges and conduct transactions. Although there are no operational time and distance based charging systems, plans exist to test the technology of TIMEZONE in the field during 1992 and progress to more extensive trials.

It would also be feasible to design a charging structure based purely on the distance travelled within a specified area. This would be directly related to the use made of roads by the individual driver. It would have the attraction that charges would be extremely predictable, based on route choice, which may, in turn, improve perceptions of fairness, as drivers would have no grounds to consider that they were being charged for congestion caused by incidents on the network, such as roadworks, failure of signals or accidents (criteria (3) and (5)). The principal drawback of this approach is that without a time element, the charging structure is unresponsive to levels of congestion, which could only be represented through pre-set charge levels for different times of day. It is probably for this reason that no firm proposals exist for solely distance based charging structures.

An additional approach to charging has been proposed to relate charges directly to the costs imposed upon other users, including those travelling later during the congested period (Smith and Ghali, 1991). This would involve either a charge levied retrospectively or a reliable method for predicting future short-term traffic patterns. It seems unlikely that such a system could ever satisfy the need for simplicity of understanding and predictability of charge level (criteria (3) and (6)), especially bearing in mind the complex effects on driver behaviour and travel decisions which could occur as the result of incurring costs which would be higher earlier in the peak and unrelated to prevailing traffic conditions. In the absence of operational evidence for the effects of time and distance based charging systems current research using modelling techniques may provide the best insight (May et al, 1991).

Although the Smeed criteria have been used throughout this review of alternative charging structures, little references has been made to criteria (5), regarding perceived fairness. This is very closely related to the equity objective of road pricing. In general it is likely that all charging structures will have winners and losers, but that the more complex the system the more it is able to address equity issues. Particular equity concerns relating to the above systems are as follows:

a)Extension of existing taxation will particularly affect lower income groups, those with the greatest need to use a car and those with no satisfactory alternative.

b)In addition to the effects in (a), supplementary licensing and cordon tolls have been criticised for resulting in inequities relating to the locations of cordon points, requiring some users to cross cordons more than others (Waersted, 1992) and the effects of transferring congestion related problems to new areas just beyond the cordon (Thorpe and Hills, 1991). It is generally accepted as unfair that short trips terminating just within a charge area pay the same as drivers travelling extensively within the cordon.

c)Supporters of congestion metering suggest that any system which levies a charge when roads are uncongested is inherently unfair (Oldridge, 1990). However, there are also inequities related to time and congestion based charging structures, where the charges for particular journeys may be difficult to predict.

With regard to the treatment of occasional users and visitors (criteria (10)), difficulties tend to correspond to the higher levels of technology beneficial to some charging structures, but precise effects depend upon the design of individual schemes.

5. TECHNOLOGY

The technology required to operate road pricing successfully depends upon the choice and complexity of the charging structure. Although supplementary licensing in Singapore has shown that totally manual operation is possible, there are benefits to be gained in terms of operating costs, speed of passage for users and, potentially, limitation of errors from automation. The technology for electronic road pricing (ERP) systems comprises three elements:

a) A procedure for levying charges.

b) A communications system between the roadside and passing vehicles.

c)Provisions for enforcement.

All three elements criteria should be designed to meet criteria (4), (7), (8), (9), (10), (11) and (12).

5.1 SYSTEMS OF PAYMENT

These are of two types (Thompson, 1990):

a) Off-vehicle recording.
b) On-vehicle recording.

Off-vehicle recording involves an electronic tag which identifies a vehicle on passing charge points, with charges being calculated by a central computer. It is not able to handle time and distance based charging, but the roadside recorder is able to incorporate time of day along with the vehicle identifier so that a complex cordon toll system could be accommodated. The principal drawback relates to objections regarding invasion of privacy, which caused this system to be rejected in Hong Kong. However, in Norway off-vehicle recording has been introduced successfully using more recently developed tag technology, involving encryption and electronic transactions, which enable charges to be deducted on line. This would allow complete privacy if all records were immediately destroyed, but would introduce potential problems regarding the accountability of the system as the user would be unable to check his transactions. A more favoured approach is the retention of transaction details in a register without any link between the tag number and the user or vehicle. This is intended to provide an acceptable level of privacy while keeping records for checking and audit purposes. Introduced on an optional basis as an alternative to manual toll collection in Norway, this system has allowed drivers to choose between time savings and any perceived privacy limitations. In addition, the adoption of a tag in the form of a portable card, similar to a smart card, allows vehicles to be equipped much more quickly and cheaply than was found to be the case in Hong Kong, where tags were permanently fixed to the underside of the vehicle.

On-vehicle recording requires an in-vehicle unit (IVU) which accepts payment from a smart card. The IVU is potentially able to handle any charging regime about which information can be provided by the vehicle or from the roadside. Cordon based charging would require the IVU to be triggered to deduct a specified charge at each cordon point. Time and distance based charging would require the IVU to be switched into and out of charging mode on passing cordon points, with additional information regarding the charging level and criteria to be used also being transmitted on entering a charge area. Thus on entering a TIMEZONE are the IVU would be switched on and provided with the relevant information regarding the cost per unit time to be deducted. For congestion metering the IVU would require information about the charge level and that of the charging threshold.

The IVU has three principal advantages over off-vehicle recording:

a) The lack of central records ensures privacy.
b) The IVU can provide immediate information regarding charges incurred.
c) The IVU technology could be extended to cover other transport costs, such as parking and public transport fares and has potential for use as part of driver information systems (Van Vuren and Smart, 1990).

There are also three disadvantages:

a) Smart cards could be stolen and would not be identifiable as easily as vehicle tags, although various measures from the consumer credit and debit card industry such as personal identification numbers (PINs) could be employed.
b) Problems of policy regarding the allowance of a credit margin on used smart cards will need to be addressed if there is no central record and new cards can simply be purchased, while an old card with a negative balance is discarded.
c) Smart cards may be open to fraud and tampering.

5.2 COMMUNICATION SYSTEMS

There are three potential means of communication between the vehicle and the roadside:

a)Low frequency radio transmission from loops in the road. This was proposed for Hong Kong, but can only be used for very limited information transfer and is only feasible over short distances.

b)Infrared technology, which has so far only been used for route guidance (Jeffrey et al, 1987).

c)Microwave technology, the focus of most road pricing work.

Both the TIMEZONE and Cambridge road pricing proposals are based around microwave beacons and the development of the technology has been the centre of the EC DRIVE PAMELA project (Blythe and Hills, 1991). The results of recent experiments have suggested that a very high level of reliability in data transfer is achievable even in heavily trafficked, high speed, multi-lane conditions (Hills, 1992).

5.3 ENFORCEMENT

It is generally agreed that enforcement of the above technology presents the greatest challenge of all. Any electronic road pricing system requires the ability to identify and classify all vehicles passing through a cordon point in order to ensure that any unequipped vehicle is not allowed to pass with impunity. This process can be carried out automatically, but in Singapore manual enforcement was required to allow a policy of free entry for high occupancy cars to be operated (Holland and Watson, 1978). Once an offending vehicle has been identified as possessing no charging facility, a permit for the wrong class of vehicle or an insufficient credit balance, it must then be identified. An IVU is capable of providing this information electronically, but the most favoured approach is the use of video recording equipment. Experience from Norway has found some problems with identification of vehicle licence plates from video recordings related to light, weather conditions and dirty number plates. In addition a hardcore of persistent offenders have been identified resorting to some lengths to avoid detection (Waersted, 1992). Measures include the removal and amendment of number plates, obstruction of plates with dirt and even the use of specially designed mechanical devices to turn or cover plates from the view of the camera. Also, there are potentially very high administration costs involved in processing large numbers of photographs, particularly if systems attempt to deal with visitors and casual users using a simple non-electronic daily permit as has been proposed with TIMEZONE (EASAMS, 1991). In this case visitors would initially be identified as potential offenders from video, but exonerated once the number plate has been checked against permit purchases. This approach also fails to protect privacy.

Finally, there is a problem to be addressed in identifying the correct authority to take responsibility for enforcement issues. In order to bring about prosecutions of offenders the body would need to be able to empower and justify penalties based upon information provided by the system technology and would need to be able to withstand the reliability of such information being questioned. What would be perceived as very minor motoring offenses may lose public sympathy and place an intolerable burden on existing services if dealt with by the conventional policing and legal systems. It is also likely that local government agencies would wish to avoid the extra administration burden and endangering their public popularity. Therefore, enforcement may be the greatest stumbling block, especially for the more complex technology based charging systems.

6. SUMMARY

This paper has taken a broad definition for road pricing and examined the full range of charging mechanisms which can be applied to private transport. The objectives of road pricing have been reviewed, during which it has been demonstrated that the practical aims go far beyond the initial arguments of economic efficiency bringing in objectives relating to environmental protection, urban planning, equity and revenue generation. The criteria for system design proposed by the Smeed Report have been set out and used to assess the range of possible road pricing systems. Four categories of charging structure have been identified:

a) The extensions of existing charging and taxation arrangements.
b) Supplementary licensing.
c) Cordon tolls.
d) Time, distance and congestion based charging.

In general it has been found that more complex charging structures allow greater flexibility and come closest to relating charges incurred to actual road use, but that maintaining a charging structure which can be easily understood by the user and can cater for visitors and occasional users is also important.

Finally, a review of road pricing technology has been carried out. This has shown that on-vehicle recording of charges is required for time and distance based pricing and that there are potential problems for invasion of privacy with off-vehicle recording. Microwave technology has been identified as the most suitable communications system for road pricing, between the vehicle and the roadside given the current state of technology. Enforcement has been argued to be the principal challenge to all road pricing methods, particularly complex systems dependent upon the performance of technology.

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