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ORIGINAL PAPER

# Overcoming the barriers to implementing urban road user charging schemes

**Anthony D. May · Andrew Koh · David Blackledge · Michela Fioretto**

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**Abstract** Urban road user charging offers the potential to achieve significant improvements in urban transport, but is notoriously difficult to implement. Cities need guidance on the range of factors to be considered in planning and implementing such schemes. This paper summarises the results of a 3 year programme which has collated evidence on the issues of most concern to cities. A state of the art report has provided evidence on 14 themes, ranging from objectives and design to implementation and evaluation. A set of 16 case studies has reviewed experience in design and implementation across Europe. The paper summarises their findings, provides references to more detailed information, presents the resulting policy recommendations to European, national and local government, and outlines the areas in which further research is needed.

**Keywords** Road user charging · Literature review · Urban transport · Scheme design · Acceptability · Implementation

## 1 Introduction

Urban road user charging (URUC) is at the same time uniquely capable of reducing the problems of urban travel, and uniquely difficult to implement. Those cities which have implemented urban road user charging have all achieved reductions in traffic entering the charging zone in the range of 14% to 23%.[1] This represents a change in travel patterns which cannot be approached by any other available transport policy instrument. Yet over the last 5 years, in which schemes have been implemented successfully in Milan, Stockholm and Valetta, ten UK cities and two US cities have decided to abandon plans for charging, despite substantial government grants designed to encourage such schemes. In Edinburgh and Manchester these decisions were made in the public glare of referenda which rejected charging proposals by majorities of 70% to 80% [43, 57]. It is clear that there are serious barriers to the pursuit of urban road user charging, and that cities need guidance if they are to make better use of this potentially powerful transport policy tool.

This shortfall, between the potential of urban road user charging and the progress of its actual implementation, has been the focus of a 3 year project funded by the European Commission: CURACAO—Coordination of Urban Road User Charging Organisational Issues. The aim of CURACAO has been to support the implementation of urban road user charging as a demand management tool in urban areas. The project did this by working with a user group of 20 cities interested in pursuing road user charging, to identify the barriers to their doing so, and to provide evidence on ways of overcoming those barriers. Evidence was provided both through a State of the Art Report, which reviewed international evidence on each of 14 themes of interest to the cities, and through a set of 16 case studies of successful implementations, current plans and abandoned proposals.

In addition to the State of the Art Report [10] and the Case Study Report [11], results have been disseminated

A. D. May · A. Koh (✉)
Institute for Transport Studies, University of Leeds,
Leeds LS 2 9JT, UK
e-mail: a.koh@its.leeds.ac.uk

A. D. May
e-mail: a.d.may@its.leeds.ac.uk

D. Blackledge
Transport and Travel Research Ltd,
Lichfield, Staffordshire, UK
e-mail: david.blackledge@ttr-ltd.com

M. Fioretto
Istituto di Studi per l'Integrazione dei Sistemi,
Rome, Italy
e-mail: m.fioretto@isis-it.com

[1] The charging scheme in Durham, UK in fact reduced traffic by up to 85% [19], however it was a unique scheme as it involved charging traffic for using a single road to access a historical peninsula.

through a set of 30 fact sheets and a "guiding presentation" [12] which presents the key messages in a flexible PowerPoint presentation. Drawing on these findings, a series of policy recommendations have been developed for cities, for national governments and for the European Commission. Throughout the project, user group cities have been directly involved in designing and commenting on the project's outputs. Working closely with particular European cities in this way has established a positive cycle of knowledge growth and development amongst the decision makers and technical experts in these cities.[2]

In this paper we summarise the main findings and policy messages from the CURACAO study. Section 2 outlines the approach to developing the State of the Art Report, while Section 3 summarises the key findings for each of its 14 themes. Section 4 describes the approach adopted in reviewing the case studies, and provides advice on the design of an effective evaluation procedure. Section 5 outlines the key findings of the case studies of implemented schemes. In Section 6 we present our policy recommendations, and in Section 7 we identify some areas in which further research is needed. Section 8 offers some conclusions.

## 2 Developing the State of the Art Report

The State of the Art Report was designed to summarise the evidence, collated from research and practice, on a series of themes of concern to cities. The final version of the report examined evidence available up to December 2008 [10]. The coverage of the report centered on the identified needs of the user group cities. An early User Needs Assessment Questionnaire [9] asked cities to assess the relative importance to them of a series of themes. Through a process of consultation, the structure of the State of the Art Report was based on the 14 themes:

1. the possible objectives of urban road user charging schemes
2. the ways in which road user charging schemes can be designed to meet those objectives
3. the technologies available to support such scheme designs
4. the business systems affecting the technology choice and operation of the scheme
5. techniques for predicting the effects of road user charging schemes
6. specific evidence on traffic effects
7. specific evidence of impacts on the environment
8. specific evidence of impacts on the economy
9. specific evidence of impacts on equity
10. techniques for appraising the effects of road user charging schemes
11. factors affecting the acceptability of road user charging schemes
12. the potential transferability of experience from one city to another
13. good practice in the implementation of urban road user charging schemes
14. techniques for monitoring and evaluating the effects of road user charging schemes.

Figure 1 illustrates the structure of the final version of the Report, and the linkages between the themes. Each section is based on a series of questions which cities might ask, and answers to those questions based on available evidence. Each section concludes with four standard sub-sections:

- implications for policy
- implications for each of the other 13 themes
- future research needs
- suggestions for further reading.

The production of the Report was overseen by a scientific committee involving experts from seven countries and six disciplines who contributed individual sections and critically reviewed the material provided by others. The requirement for each section to discuss implications for other themes provided a valuable check on the consistency and coverage of the Report. The first edition was critically reviewed by four international experts from Australia, Hong Kong, Singapore and the US. Their role was to ensure that the structure and findings were sound and that evidence from outside Europe was being accessed. As a result, significant modifications were made to the second edition. All three editions were also reviewed by the user group of cities to ensure that the focus was relevant to their needs, and the opportunity was taken to present and test each section in one of the series of six public workshops. The production of the fact sheets and guiding presentation, both of which needed succinct summaries of complex material, provided a final check that the key policy implications were being drawn and justified.

## 3 The key findings of the State of the Art Report

### 3.1 Possible objectives and strategy

The report has identified a set of nine possible objectives, listed in Table 1, which appear to reflect the full range of objectives for which urban road user charging is likely to be pursued by cities. Among these, efficiency, environment and revenue generation remain the dominant objectives.

Road user charging design should follow a logical sequence, in which the overall strategy is determined first,

[2] Information published by CURACAO is available on the website http://www.curacaoproject.eu/

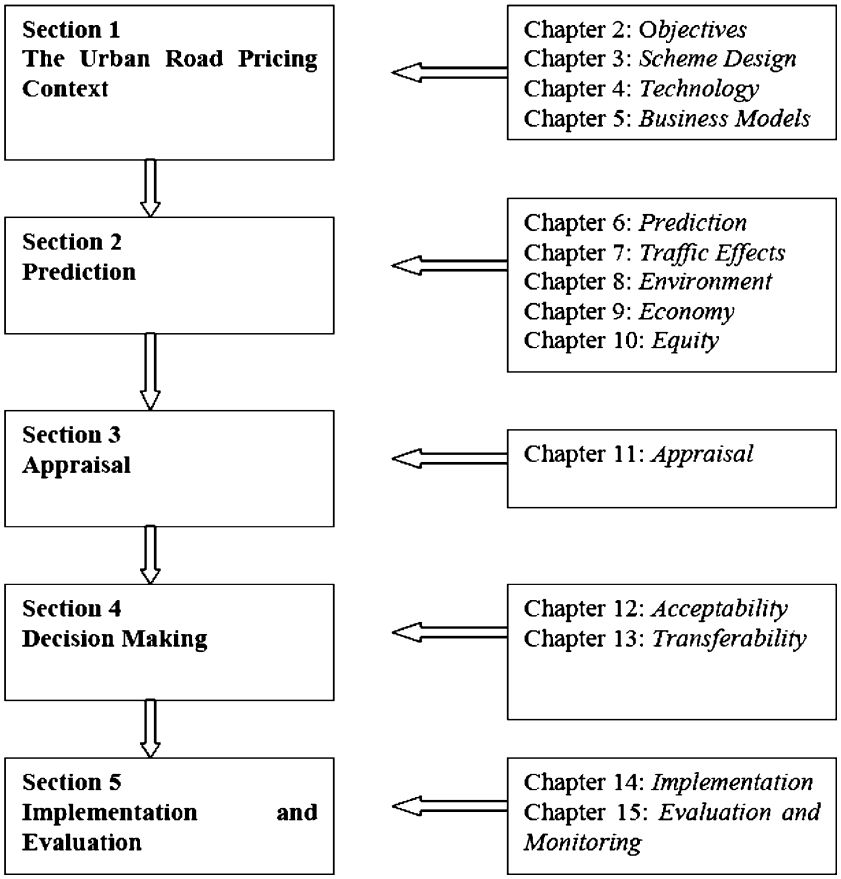


**Fig. 1** Organisation of the State of the Art Report, [10]

and the role of road user charging determined as part of that strategy. This will help to demonstrate that road user charging is needed. Road user charging will be more effective if integrated with other policies [64]. Research on integrated strategies has demonstrated that road user charging is a key element of an effective strategy, and is best complemented by actions to promote public transport, to reallocate road space and to manage land use [35, 41]. These measures are also likely to reduce the adverse impacts of urban road user charging on those travellers who are most disadvantaged by it, and increase its acceptability [42]. However, the best combination of these policy instruments will depend critically on the city context in which they are being applied.

**Table 1** Possible objectives of a road user charging strategy

| |
|---|
| Congestion Relief |
| Environment |
| Revenue Growth |
| Economic Growth |
| Health |
| Liveability |
| Safety |
| Equity/Social Inclusion |
| Future Generations |

### 3.2 Scheme design

Road user charging should be designed in the context of the selected complementary policies. The design principles, listed below, which were first outlined over 40 years ago in the UK Smeed Report [45] continue to remain valid today.

1. Charges should be closely related to the amount of use made of the roads.
2. It should be possible to vary prices to some extent for different roads (or areas), at different times of day, week or year, and for different 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 under certain conditions.
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 used should possess a high degree of reliability.
8. The method should be reasonably free from possible fraud and evasion, both deliberate and unintentional.

9. The method should be capable of being applied, if necessary, to the whole country and to a vehicle population over 30 million.

As a result of technological advances [29, 49], road pricing can now be implemented in a number of ways, using point charges, cordons, area pricing or distance-based pricing. There is increasing evidence that distance-based pricing is the most efficient [39]. However, it appears that many cities will wish to rely on cordon and area-based schemes [40] which have the merit of being simple to understand. The selection of charging points in a cordon is critical to the effectiveness of a charging scheme [40]. In practice, it is often the case that the choice of these charging points is a matter of professional judgment. Methods have now been developed to determine cordon locations which have been shown to be two to three times as effective as cordons designed through professional judgment alone [63].

Whatever the charging system, the design will need to determine the level of charge, variations by vehicle type, location and time of day, and exemptions and discounts [8]. All these elements of charge specification will affect the effectiveness of the scheme. Early analysis of proposals for London demonstrated that an optimum charge can be identified for any charge specification, and that benefits can fall rapidly if the charge is set too low or if the optimum is exceeded. It also demonstrated that different specifications, with different numbers of cordons and different variations between peak and off peak, performed very differently [38]. Subsequent work has shown that level and complexity of charge also affect a scheme's acceptability [30].

Trade-offs will almost certainly be needed between effectiveness and acceptability, as discussed further in Section 3.11 below. There is also a strong practical case for keeping the overall design as simple as possible. As [3] have shown, drivers are much less likely to be able to predict, and respond effectively to, charges which are levied in complex ways. The important role of exemptions and discounts in increasing acceptability should not be overlooked, but care is needed to avoid these substantially reducing benefits [56], or imposing excessive costs [23].

### 3.3 Technology

Technology and business systems should be specified in terms of the scheme design, rather than imposing constraints on it. Technologies are required for charging, payment and enforcement. The principal technologies are automatic number plate recognition, dedicated short range communications and global navigation satellite systems. The last of these, in particular, is experiencing rapid development and should in due course enable a wider range of pricing systems, including distance-based charging. However, automatic number plate recognition remains the principal tool for enforcement [29, 49]. Protection of privacy should be feasible with all technology options.

### 3.4 Business systems

Business systems are needed to manage the complex and interacting requirements of monitoring, payment, accounting and enforcement. While such systems are widely available in the private sector [32], they are still being developed for complex public sector applications such as road pricing [14]. Choice of technology and of business systems will have a significant impact on operating costs and, together with charge levels, will affect the net revenues available for investment. Table 2 indicates the substantial variation in revenue recovery between schemes [20].

### 3.5 Prediction

The performance of urban road user charging schemes will depend critically on the behavioural responses induced. It is important to identify the full range of both first and second order responses, and to understand their likely levels. In particular, motorists can be expected to change mode, route, destination, timing and number of journeys. Those who use bus and rail or walk or cycle may make similar changes. Similar types of response can be expected from freight operators and drivers. Second order effects will include changes in vehicle ownership and fleet composition, as well as in the location of economic activity, homes and jobs. Comprehensive guidance is now available in the UK on ways of representing each of these responses [15, 16].

There is now increasing experience of methods for predicting these impacts of urban road user charging schemes. The AFFORD project [44], identified five types of modeling framework, and assessed their ability to represent the effects of urban road user charging. Ordered in terms of decreasing scale of spatial resolution, these categories are as follows:

- Detailed simulation models which provided very detailed estimates of network effects and allowing travel conditions to vary continuously during the modelled time period,
- Tactical network models which focus on spatial redistribution of traffic on transport networks in response to changes in costs,
- Strategic transport models which focus on travel demand choices but may often lack explicit transport networks,

**Table 2** Charges, income and operating costs of schemes in 2005

| | Average charge | Annual revenue (millions €) | Operating costs as a percentage of revenues |
|---|---|---|---|
| Austria | € 0.27 / km (40 tonne truck) | 770 | 9% |
| Germany | € 0.12 / km (40 tonne truck) | 2 860 | 16%[a] |
| Switzerland | € 0.67 / km (40 tonne truck) | 800 | 4% |
| London | € 7.4 / day | 275 | 48% |
| Stockholm[b] | € 2.7 / day | 80 | 25% |
| Singapore | € 0–2 per trip | 39 | 7% |

Source: [20]

[a] Including costs of deployment, construction, operation and development of the infrastructure network

[b] Stockholm figures for 2006

- Geographic models which focus on the long run interaction of transport systems land use decisions,
- General equilibrium models which focus on the impacts of the transport sector within the wider economy.

The complexities of road user charging make prediction particularly difficult, especially where economic, distributional and equity impacts are concerned. Despite this, experience in London and Stockholm suggests that it is possible to predict the effects of urban road user charging on traffic levels reasonably reliably. In these two cities, a strategic transport model was used in combination with a tactical network model for the predictions. In London, traffic reductions of 15% to 20% were achieved, as compared to predictions of 15% [70], while in Stockholm, the actual reduction of 22% in traffic crossing the cordon compared with a prediction of 25% [21].

### 3.6 Traffic effects

Those urban road user charging schemes which have aimed to reduce traffic have typically reduced traffic entering the charged zone by between 14% and 23% [6, 7, 68, 74]. This is one of the highlighted impacts summarised in Section 5 below. Changes in the Norwegian Toll Rings, which aimed to generate revenue rather than reduce traffic, have been much smaller [47]. Effects on speeds and congestion have been more variable. The London scheme reduced congestion by 30% initially, but this has since been eroded by extraneous factors which have temporarily reduced road network capacity, and by intentional reallocation of road space [33, 74]. Stockholm experienced a one third reduction in delay in the charged area, which has been sustained subsequently [68].

### 3.7 Environment

Road user charging will have a wide range of impacts on the environment, some of which are easier to quantify than others. Most impacts, arising from reduced traffic, will be beneficial. There should be an overall reduction in carbon emissions, as well as reductions in local pollutants and noise. For the latter, the effects on immissions will be particularly large where reductions in traffic occur in densely populated areas [65]. Tables 8 and 9 (in Section 5) show the observed reductions in carbon dioxide and pollutants within the charging zones for the case study cities. It is important to note, though, that redistribution of traffic outside the charged zone may have negative impacts. As [46] found in a desk study for Leeds, the distribution of changes in emissions is very sensitive to scheme design, and can raise concerns over environmental justice [18]. However, careful design can minimise these redistributional effects, and road user charging and the policies which complement it can be designed to focus the benefits more directly on environmental enhancement [30].

### 3.8 Economy

The business community is likely to be critical of the potential impact of road user charging on the urban economy [28, 68] unless it can anticipate substantial benefits through congestion relief [36]. Although there is still only limited evidence to counter such fears, the evidence that does exist does not support them. Much still comes from predictive models, which have typically indicated that urban road user charging would only alter population and employment in the affected areas by between +1% and −3% [22, 38, 67]. Some empirical evidence is now becoming available. An early study in Trondheim [77] found that a decline in annual turnover prior to the toll ring was reversed after the toll ring had been implemented, and concluded that there was no evidence that the toll ring had adversely influenced trade. A similar finding has arisen recently in Stockholm [13]. More detailed analyses have been conducted in London, where some firms have argued that they have lost market share [52], but the general consensus is that road user

charging has had a broadly neutral effect on the London economy [24, 74]. Thus, while the evidence remains limited, it is increasingly clear that the impacts of road user charging on the urban economy are likely to be small and, in particular, much smaller than the business community predicts.

### 3.9 Equity

The assessment of equity implications relies on the clear identification of the relevant impact groups, and on assessment of the extent to which each is likely to be affected. Good practice on the listing of such groups is now available [17, 34]. However, for many such groups the prediction of impacts remains uncertain, particularly given the difficulty of modelling distributional impacts (Section 3.5). An important distinction can be made between "horizontal" factors such as location, demography and transport needs, and "vertical" factors related to income. Evidence from the US suggests that, for HOT lanes at least, there is little evidence of "vertical" inequities [55, 78]. For road user charging schemes, the situation is more complex, since lower income travellers are more likely to be bus users, and hence benefit from reductions in congestion. The limited analysis available suggests that the net difference in impact between income groups is relatively small. Conversely, studies have shown that the "horizontal" inequities can be substantial, particularly as between those living within and outside charging cordons [2, 26]. Potential inequities can be reduced by modifying the scheme design, revising charge levels and exemptions, and using the revenues to provide alternatives and complementary policies [75].

### 3.10 Appraisal

Appraisal of urban road user charging proposals needs to reflect the full range of objectives adopted by the city concerned. Table 4 (in Section 4) indicates the appraisal table developed within CURACAO to reflect the range of impacts of interest to participating cities. It is important to specify clearly whether the appraisal is limited to the road user charging scheme itself, the scheme together with any complementary measures, or in addition any measures financed from surplus revenue. Appraisal requirements are in many ways similar to those for any transport policy intervention [48], but the scale of the changes induced by road user charging, and its role in generating revenue makes appraisal more complex. A full cost benefit analysis requires each impact to be measured (or for future schemes, predicted) and to be assigned a monetary value. Table 3 summarises the assessment in CURACAO of the ease with which performance against each of the key objectives can be quantified in these ways. Detailed guidance on good practice in the appraisal of road user charging schemes is now available [16].

### 3.11 Acceptability

Acceptability can be defined as the prospective judgement by individuals, interest groups or politicians of a measure to be implemented in the future [60]. It remains the principal concern of cities considering urban road user charging. Acceptability is mainly based on personal outcome expectations, which are typically negative [58] Evidence on the impacts of scheme design on acceptability is inconsistent. Several authors have found little correlation between acceptance and proposed charge level, while others have found that acceptability falls as the charge level increases [4, 30]. [59] found little difference in acceptability for cordon, distance and delay-based charges, while several studies have shown that more complex schemes are likely to be less acceptable [3, 79, 80].

There is increasing evidence that levels of acceptability are highly dynamic, and in particular are likely to decline as the proposal becomes more concrete and more imminent, and increase again after implementation [61]. Toll rings in Bergen and Trondheim would have been rejected by a significant majority before implementation, but attracted majority support a year after implementation [47]. In London the proportion opposed fell from 40% before implementation to 25% a year later [71], while in Stockholm opposition fell from 55% to 41% over a similar period [66]. This helps explain why referenda held immediately before implementation are particularly unsuccessful [27].

Acceptability can also be increased by the provision of alternatives and by the use of discounts and exemptions [30]. There is potentially a conflict between pursuit of acceptability, through lower charges and increased use of discounts, and pursuit of effectiveness, which may require higher charges and fewer exemptions [79]. The introduction of complementary policy instruments and the use of road user charging revenue to support such policies are critical to increasing acceptability [30, 31, 59, 62].

### 3.12 Transferability

Transferability concerns the ability of a scheme and its resulting impacts to be replicated in another city. The issue of transferability of policy from one city to another has attracted relatively little study, despite early work by [54] and a fuller analysis by [76]. Transferability remains a little understood aspect of urban road user charging policy, partly because most schemes are very different, and partly because of the lack of empirical results. CURACAO itself encouraged a process of policy learning among participat-

**Table 3** Ease of appraising different objectives

| Objective | Easy to measure? | Easy to predict? | Easy to assign a monetary value? |
|---|---|---|---|
| Congestion relief | Yes | Yes | Yes |
| Environment | Yes | Limited | Limited |
| Revenue Growth | Yes | Yes | Yes |
| Economic growth | Yes | Limited | No |
| Health | Limited | No | No |
| Liveability | No | No | No |
| Safety | Yes | Yes | Yes |
| Equity/ Social Inclusion | Limited | No | No |
| Future generations | Limited | Limited | No |

ing cities, and recent research has demonstrated more fully the way in which cities have been learning from one another [37]. It appears that the main focus has been on transfer of technology, business systems and implementation and evaluation processes, rather than the specifics of scheme design.

### 3.13 Implementation

Implementation processes have also been less fully researched than other aspects of scheme design. Winter's integrated implementation model [1] and CUPID's implementation actions [8] offer a useful structure for comparing approaches in different cities. Comparisons within CURACAO demonstrate that implementation processes, and their related legislative frameworks and political structures, differ substantially from one city and country to another. However, it is clear that political commitment is crucial, and the timing of implementation needs to be matched closely to the electoral cycle. Ideally a consensus should be developed at a regional level to avoid conflicts between adjacent authorities. It will be important not to underestimate the timescale needed for the full implementation process.

### 3.14 Monitoring and evaluation

Effective monitoring of all impacts of a scheme will be important in sustaining and enhancing the scheme. The sequence of reports from Transport for London illustrates good practice in monitoring, and demonstrates the benefits of such a programme [69–74]. The monitoring programmes in London and Stockholm have also contributed significantly to the body of empirical evidence on urban road user charging.

Results from such monitoring programmes can be used to conduct a comprehensive evaluation of implemented schemes. Ideally, such evaluations should consider the full range of nine possible policy objectives identified in Table 1, so that lessons can be learnt by other cities. Evaluation should be carried out using similar procedures, assumptions and values to those adopted for appraisal (Section 3.10). In this way it should be possible to assess how well the prediction process (Section 3.5) has worked [23].

However, the performance of a road user charging scheme, as measured by an evaluation process, will depend critically on the coverage of the evaluation, and the values assigned to individual elements. This is illustrated well by the critical evaluations of the London and Stockholm schemes conducted by Prud'homme [50, 51]. In both cases they presented road user charging in a far less favourable light than did the cities' own evaluations, principally by adopting different assumptions as to what should be included and how each item should be valued. It is thus important that the basis for the evaluation is agreed in advance and, ideally, is specified in a consistent way by all cities involved. As the IMPRINT-Net project has noted, evaluation of road user charging schemes remains the weakest area of policy development [53].

## 4 Evaluating the case studies

The Case Study Results Report [11] is based on the collection of case studies from the leading European cities in the field of urban road user charging. The good practices gathered concern three types of city:

- Cities in which URUC schemes have been implemented (such as London, Stockholm, Oslo)
- Cities in which URUC schemes are under design (such as Bristol, Cambridge)
- Cities in which URUC schemes have been rejected (such as Manchester, Edinburgh)

Based on the structure of the State of the Art Report, the Case Study Results Report focused among other things on pricing objectives, scheme design, implementation process and scheme results.

The original intention was to establish a set of baseline indicators and collect data on these indicators from the core

cities. The starting point was to develop a simple but solid common indicator-based framework, while recognising that the core city case studies are quite diverse in nature and stage of implementation. The framework developed, which included both quantitative and qualitative indicators, is shown in Table 4.

The individual nature and characteristics of the case studies, coupled with the fact that they were at different stages of road user charging implementation, called for a pragmatic approach, particularly since the project had no resources to collect new data.

The next step was to establish a baseline by collecting common indicator data for the time period preceding the implementation of any urban road user charging schemes. The second phase of data collection was intended to involve collection of similar indicator data after implementation in order to evaluate the schemes' results.

During 2007 and 2008, the project partners collected together all available indicator data, but it proved to be insufficient as a basis for drawing detailed conclusions about the impacts of urban road user charging and in particular for a 'compare and contrast' exercise between the cities. For instance, out of the six core project partner cities, only four had actually implemented schemes, and there were difficulties in obtaining certain categories of data from Rome and Oslo.

In spite of these difficulties, data was also becoming available from other cities with implemented schemes, such as Bologna and Milan. Therefore a revised methodology was agreed that would collate available data from the 16 case studies to provide a set of key indicators. Having collated the case studies and the corresponding key indicators, it has been possible to produce a comparative Impact Assessment of the main results, subdivided into seven key "headline" areas of impact. The full list of case studies reported in CURACAO is shown in Table 5.

## 5 Principal findings from the case studies

There are seven key 'headline' impacts that can be drawn from an analysis of the case study data, showing that urban road user charging is a demand management tool which can deliver a wide range of benefits.

### 5.1 Impacts on the traffic network

The first key message drawn from the case studies is that URUC can have a powerful impact on reducing the amount of vehicle traffic entering the charging zone of the city during the period of operation. The CURACAO case studies have shown that in response to the implementation of URUC, a proportion of travellers will change their travel behaviour, either changing modes, moving their trips to times outside the hours of operation, combining several trips into one, or foregoing travel completely. Correspondingly, there will be increases in the use of other modes of travel—public transport and cycling. Additional provision for public transport might have been made as part of the package of measures accompanying the introduction of URUC, as has been the case in London and Stockholm. The changes in traffic levels entering the zone for a number of cities are shown in Table 6. It should be noted that the result for Durham is atypical, since charges were imposed on the single entry point to a restricted area.

The second key message drawn from the case study data is that URUC can significantly reduce traffic delays within the charging zone during the period of operation. With fewer vehicles in the zone, average vehicle speeds can be increased, and journey time reliability improved. The main objective of a 'congestion charging' scheme can therefore be met. The reduction in delays recorded by the two cities where it has been measured is shown in Table 7.

### 5.2 Impacts on the environment

The third key message drawn from the case study data is that URUC can significantly reduce carbon dioxide emissions from traffic within the charging zone. This effect is principally caused by the reduction in the number of vehicles in the zone, but other factors include a higher proportion of 'green' vehicles travelling into the zone, due to charging exemptions, and more efficient engine operation as traffic flows are smoothed. The reduction in carbon emissions in the zone recorded by a number of cities is shown in Table 8.

The fourth key message drawn out from the case study data is that URUC can significantly reduce the local emissions (oxides of nitrogen ($NO_x$) and particulate matter ($PM_{10}$)) measured within the zone. In common with carbon dioxide emissions, this effect is principally caused by the reduction in the number of vehicles entering the zone, and smoother traffic flows. The reduction in pollutant emissions in the zone recorded by a number of cities is shown in Table 9.

### 5.3 Impacts on the safety

The fifth key message drawn from the case study data is that URUC can reduce the number of road traffic casualties within the zone. This effect is related to the reduction in the overall number of vehicles in the zone. While increased speeds can lead to more accidents, this is offset by the overall reduction in traffic. The reduction in casualties recorded by Milan is shown in Table 10.

**Table 4** Proposed evaluation indicators in urban road user charging schemes

| | Impact area[a] | Indicator | Quantitative indicator | Qualitative indicator |
|---|---|---|---|---|
| | **Efficiency** | | | |
| 1 | | Change in Average vehicle speed | ■ | |
| 2 | | Feeling about traffic conditions | | ■ |
| 3 | | Traveller perception of RUC system reliability | | ■ |
| 4 | | Change in number of vehicles entering the zone | ■ | |
| 5 | | Modal split | ■ | |
| | | | | |
| | **Equity** | | | ■ |
| 6 | | Level of user acceptance | | ■ |
| 7 | | Level of perception of fairness | | ■ |
| 8 | | Index of opinions from the different user groups | | ■ |
| 9 | | Index of opinions on ease of access | | ■ |
| 10 | | Level of user awareness | | ■ |
| | | | | |
| | **Environment** | | | |
| 11 | | Change in $CO_2$ emissions | ■ | |
| 12 | | Change in CO emissions | ■ | |
| 13 | | Change in NOx emissions | ■ | |
| 14 | | Change in particulate emissions | ■ | |
| | | | | |
| | **Scheme Finances** | | | |
| 15 | | Investment cost | ■ | |
| 16 | | Operational and maintenance system costs | ■ | |
| 17 | | Revenue from charges | ■ | |
| 18 | | Revenue from fees | ■ | |
| | | | | |
| | **Safety** | | | |
| 19 | | Level of perception of security conditions | | ■ |
| | | | | |
| | **Health** | | | |
| 20 | | Level of perception of air quality into the zone | | ■ |
| | **Liveability** | | | |
| 21 | | Level of perception of on-street liveability | | ■ |
| | | | | |
| | **Land Use** | | | |
| 22 | | Change in housing location | | ■ |
| 23 | | Change in activity locations | | ■ |
| 24 | | Change in parking | | ■ |
| 25 | | Change in trip destinations | | ■ |

[a] "Urban Economy" should be added as an additional impact area in future evaluations. Although it has been reviewed in the CURACAO case studies there is a lack of reliable data on which to base firm conclusions other than that any impacts appear to be small. Despite this, it is regarded by users (local authorities) as a key impact area

## 5.4 Impacts on the city finances and the economy

The sixth message drawn from the case study data is that cities which have implemented URUC have achieved significant levels of revenue for reinvestment. After initial set up costs and running costs are taken into account, URUC schemes can generate significant streams of funding for public transport and other transport improvements. Indeed in many cases the provision of extra capacity in public transport is a key prerequisite before URUC is introduced.

**Table 5** CURACAO case study cities

| Country[a] | City | Scheme Type | Status at December 2008 (and year of implementation) |
|---|---|---|---|
| United Kingdom | Bristol | Area or Cordon | Planning Phase |
| | London | Area | Implemented 2003 |
| | Durham | Area | Implemented 2002 |
| | Cambridge | Cordon | Planning Phase |
| | Edinburgh | Cordon | Rejected 2005 |
| | Manchester | Cordon | Rejected 2008 |
| Netherlands | The Hague | Trial | Concluded |
| | National Scheme | Distance based | Planning Phase |
| Italy | Rome | Area | Implemented 1989 |
| | Milan | Area | Implemented 2008 |
| | Bologna | Area | Implemented 1989 |
| Norway | Oslo | Cordon | Implemented 1990 |
| | Trondheim | Cordon | Operated between 1982 and 2005 (scheme no longer in operation) |
| | Bergen | Cordon | Implemented 1986 |
| | Nord-Jæren | Cordon | Implemented 2001 |
| Sweden | Stockholm | Cordon | Implemented 2007 |

[a] Details of the schemes can be found in CURACAO [11] and are also available on the website http://www.curacaoproject.eu

It should be noted that actual scheme revenues can turn out to be less than those estimated prior to implementation, due to the number of exempted vehicles (Stockholm case), and the generally higher than anticipated reduction in traffic levels (London case). For the Italian schemes, while data is available for overall revenues from tickets, passes and fines, it has not been possible to obtain data on net revenues after the scheme running costs have been deducted, except the case of city of Rome. The revenues raised for cities for which figures are available are shown in Table 11.

The seventh and final key dimension considered has been the impact of URUC schemes on the urban economy. Generally, it can be stated that no negative impacts were faced after the implementation of URUC schemes. The appraisal of urban economy issue turned out to be difficult, and necessarily tentative, for four reasons. Firstly, the congestion charging scheme in most case studies is relatively recent and short-term behavioural reactions may not hold in the medium-term. Some of the changes induced by the charge (for instance changes in business location) will require several years to materialise. Secondly, some of the recorded changes in transport patterns (which are often uncritically attributed to the congestion charge) may in reality be caused by exogenous events.[3] Thirdly, in some cases the congestion charge could be the most important element, but not the only one, of the policy changes that a city might have introduced during the same period (e.g. increase of bus supply). Fourthly, there is very little information regarding events outside the charged zone which may have a larger impact on the economy than the charge itself. However, where empirical evidence is available, it suggests that the impacts on the urban economy are small, and typically positive.

[3] An example could be the drop in London subway patronage in 2003, which is mostly the consequence of the temporary closure of a subway line due to an accident.

## 6 Policy recommendations

Based on the evidence collated in the State of the Art Report and the Case Studies a series of Policy Recommendations have been developed. Urban road user charging will typically be the responsibility of city and regional authorities, but national governments and the European Commission have important enabling roles. The recommendations are thus aimed at all three levels of government. References in parentheses indicate the evidence on which these recommendations are based.

### 6.1 City and regional authorities

Before considering urban road user charging as a sustainable urban transport strategy, City and Regional Authorities should specify their objectives clearly, briefly and simply, and should adhere to them consistently (Sections 3.1 and 3.11). There is a case for keeping the list of objectives short

**Table 6** Change in number of vehicles entering the zone

| City | % change | Notes |
|---|---|---|
| Bologna | −23% | Access reduction in LTZ during charging hours on a working day, 2004–2006 [6] |
| Durham | −85% | From over 2000 to approximately 200 vehicles per day [19] |
| London | −16% | Percentage change in vehicles, 2006 figures versus 2002 figures, during charging hours (0700–1830). [74] |
| Milan | −14% | Decrease in vehicles accessing the Ecopass Zone (2007 versus 2008) [7]. |
| Rome | −18% | From October 2005 to May 2008. [Unpublished Internal Report] |
| Stockholm | −22% | Overall reduction in traffic crossing congestion charge cordon during charging period (0630–1829 weekdays) during the trial period. [68] |

and simple, while not omitting objectives to which road user charging could effectively contribute (Section 3.1). A road user charging scheme should not be designed in isolation but in the context of the full range of complementary policies that will support it (Section 3.1). City and Regional Authorities should be flexible and dynamic in their approach to scheme design and development, while ensuring that scheme performance is as effective as possible (Section 3.2). The scheme design should not be technology driven. Technology and Business Systems should be carefully selected with a close eye to system costs (Sections 3.3 and 3.4).

City and Regional Authorities designing a road user charging scheme should allocate resources for establishing baseline conditions, for collection of traffic and other data for analysis, and for continuous monitoring of performance after implementation (Section 3.14). Cities which implement road user charging schemes are strongly encouraged to evaluate them against the full set of objectives listed in Table 1 (Section 3.14). Acceptability should be addressed at the outset in all its different aspects. Acceptability can be enhanced by demonstrating that there is a serious problem to be overcome, that a measure as dramatic as road user charging is needed, and that it is likely to work. It is essential that the impacts, both positive and negative, are clearly identified and effectively communicated. A continuing dialogue is needed with the public, pressure groups, politicians and the media. In particular politicians need to understand, but not over-estimate, the concerns of the public (Section 3.11).

The use made of road user charging revenues is critical to determining the acceptability and effectiveness of the scheme (Section 3.11). Most charged drivers will initially be made worse off by road user charging, and it is only when the revenues have been channelled into transport (or other) improvements that they begin to appreciate the personal benefits. It is thus particularly important that the costs of operating road user charging schemes are kept as low as possible. It is also essential that the surplus revenues are available to the city authorities to use in support of their overall strategy (Sections 3.1 and 3.11).

Before implementing road user charging, city and regional authorities should pay careful attention to the planned implementation process and endeavour to establish a consensus among all the agencies involved. Wherever possible, the normal planning process should be used to judge the road user charging scheme and its complementary instruments. Unless there is a legal obligation to hold a referendum, authorities should be cautious in using this method to determine whether or not road user charging is introduced (Section 3.11).

### 6.2 National governments

National governments have a responsibility to develop a clear national transport strategy, to explain it clearly and consistently, to indicate who is likely to gain and lose from that strategy, and to take steps to compensate those who are likely to lose. As part of that strategy they should recognise the potential benefits of road user charging as a means of demand management at both local and national levels. The application of road user charging should be seen as part of a wider strategy involving the internalisation of external costs and the adjustment of road and vehicle taxation systems so that user charges vary according to location, time and type of vehicle (Section 3.2).

National governments also need to ensure that appropriate legislation exists to allow local authorities to plan and

**Table 7** Change in level of congestion in the zone

| City | % change | Notes |
|---|---|---|
| London | −30% | Reduction in average delays in minutes per kilometre, 2002 versus 2004 figures. The largest reductions were recorded in 2003 and 2004 and average delays returned to pre-charging levels by 2007 [74]. |
| Stockholm | −33% | The reduction in delay experienced by inbound traffic during morning peak from [68]. |

**Table 8** Reduction in carbon dioxide emissions in the zone

| City | % change | Notes |
|---|---|---|
| London | −16% | Change between 2002 and 2003 [74]. |
| Milan | −14% | Change after first 9 months of operation of scheme [7]. |
| Rome | −21% | Change in mean values between 2001 and 2004. [Unpublished Internal Report] |
| Stockholm | −13% | Following the trial period, Jan–July 2006, Inner City. [68] |

implement schemes, to provide the governance which enables city and regional authorities to implement both road user charging and the policy instruments which will complement it, and to stimulate strong political leadership at local levels. Finally they need to provide support to ensure that implemented schemes are effectively monitored and their results disseminated (Section 3.13).

### 6.3 The European Commission

The Commission should publish guidance for authorities interested in considering road user charging as a policy option based on the work of CURACAO. They should give financial support to:

- cities to finance feasibility studies addressing ways to reduce congestion and improve the environment (including road user charging options) and to support research and demonstration projects in provincial cities that specifically address key issues: acceptability, governance requirements for effective implementation, economic and equity impacts (Section 3.14),
- educational campaigns, training schemes and toolkits explaining the rationale for URUC as one option in the panoply of measures available to transport planners, and encouraging citizen and stakeholder involvement in discussion of approaches to tackling sustainable mobility issues (Section 3.11),
- research into standardisation and interoperability of road user charging systems and technologies (Section 3.3).

In any consideration of institutional structures and governance issues, the European Commission should bear in mind the need for governance structures which enable city authorities both to implement road user charging and the policy instruments which complement it, and to collect and use scheme revenues in accordance with policy objectives (Sections 3.1, 3.11 and 3.13).

## 7 Further research needs

The CURACAO State of the Art Report has reviewed, synthesised and summarised the evidence available from implemented urban road user charging schemes on their characteristics and impacts. The final version of the report contains a wealth of information on the 14 themes that have been studied. The number of implemented schemes is still quite small and the availability and quality of data varies considerably, however, which inevitably means that there are a number of gaps in our knowledge and understanding of the subject. These are summarised in Table 12, which suggests a priority ordering of the different topics.

## 8 Conclusions

Over the 3 year period from April 2006 to March 2009, CURACAO monitored developments in Urban Road User Charging in Europe and extended the knowledge base established by previous projects in order to provide tools to support decision-making. During this period there were some significant developments:

- Stockholm implemented a full-scale trial of congestion charging and introduced a permanent scheme following a positive referendum result.
- A trial giving monetary incentives to drivers who did not use congested roads at peak hours took place in The Hague.
- A second toll ring was introduced in Bergen.
- The scheme in Rome was extended to new areas and to evenings and weekends.
- Valletta introduced a charging scheme for using city centre roads.
- In London, a Western Extension to the original charging zone was introduced but is now almost certain to be withdrawn.
- The Dutch government brought forward proposals for a national scheme to change the existing road and vehicle taxation system in favour of a scheme in which charges will vary by time, place and the pollution class of the vehicle.
- The UK Department for Transport funded feasibility studies in a number of cities embracing packages of measures including a charging element. Manchester was the first city to receive Government approval for a scheme but failed to attract public support, raising questions over other potential schemes.

**Table 9** Reduction in pollutant emissions in the zone

| City | % change $NO_x$ | % change $PM_{10}$ | Notes |
|---|---|---|---|
| London | −13% | −15% | Change between 2002 and 2003 [74] |
| Milan | −17% | −18% | Before and after the scheme implementation [7] |
| Rome | – | −11% | Change in mean values between 2001 and 2004. [Unpublished Internal Report] |
| Stockholm | −8% | −13% | Following the trial period, Jan–July 2006, Inner City [68]. |

**Table 10** Reduction in accidents in the zone

| City | % change accidents | % change injuries | Notes |
|---|---|---|---|
| Milan | −14.4% | −14.2% | Accidents within the Ecopass area after first year of operation [7] |

**Table 11** Additional finance for investment

| City | Annual Revenues | Notes |
|---|---|---|
| London | € 140 M | Net revenues 2006–7 [74] |
| Rome | € 51 M | Estimated net annual revenues. [Unpublished Internal Report] |
| Stockholm | € 52 M | Estimated annual revenues [68] |

**Table 12** Research gaps

| Research gap | Priority[a] |
|---|---|
| The interaction between acceptability and effectiveness | 5 |
| The extent to which results in one city can be transferred to another | 5 |
| The implications of design and technology for enforcement | 4 |
| The performance of new developments in technology and in business systems | 4 |
| Ways of reducing the costs of technology and business system applications | 4 |
| The impacts on the urban economy, and in particular the differential effects by economic sector and size of firm | 4 |
| The effects of road user charging on different impact groups | 4 |
| The interaction between acceptability and equity and in particular the impact of scheme design on perceived inequity which engender acceptability issues | 4 |
| The requirements for sustaining and adapting road user charging schemes once implemented. | 4 |
| Comparisons between predicted and actual impacts, including impacts in cities where URUC was proposed but has not been introduced. | 4 |
| Approaches to the design of overall strategies which include road user charging | 3 |
| Methods for the design of road user charging schemes | 3 |
| Prediction methods | 3 |
| Understanding of behaviour, and particularly second order responses and the behaviour of users of other modes | 3 |
| The impacts of road user charging on liveability and health | 3 |
| The dynamics of acceptability over time and the particular role of referenda in testing and promoting acceptability | 3 |
| The specification of appropriate timescales and sequences for the implementation of urban road user charging schemes | 3 |
| The measurement of congestion and travel time reliability | 2 |
| Development of best practices for evaluation of RUC schemes | 2 |
| Methods of appraising second order effects | 1 |

[a] 5 = highest priority, 1 = lowest priority

- The Milan Ecopass scheme was introduced.
- The Oslo toll ring was extended and prolonged for another 20 years.
- A number of cities began studies of URUC schemes, including: Amsterdam, Copenhagen, Gothenburg, Helsinki, Bath, Ljubjana, Riga and Zagreb.

CURACAO documented developments up to the end of December 2008, and produced a range of products to meet the needs of cities as expressed by the User Group. The project attempted to draw comparisons between schemes, but this proved to be extremely difficult. Although at first sight schemes may appear to be similar, detailed scheme objectives and designs vary widely from city to city, and the available data on impacts is often inconsistent. The project identified a number of research gaps highlighting topics where information is difficult to find or is inconsistent, and which could usefully be pursued in future projects.

The European Commission's Green Paper "Towards a new culture for urban mobility" [5] raised the issue of the role of road user charging in future transport policy, while the draft report prepared by the Committee on Transport and Tourism of the European Parliament on an action plan on urban mobility [25] calls for the Commission to draw up a report on urban charging. As an input to this process the CURACAO consortium submitted some interim recommendations as part of the public consultation on the Green Paper. These were refined into the Policy Recommendations listed in Section 6, which are aimed at city and regional authorities, national governments and the European Commission. Widespread adoption of road user charging will require authorities at all levels to approach the subject with a degree of harmony, and the European Commission is particularly well placed to take the initiative in this.

Urban Road User Charging remains a controversial subject, but the significant impacts on travel behaviour that have occurred in all implemented schemes demonstrate its power as a policy instrument. Further research and monitoring of existing and new schemes as they develop would increase our understanding of the key issues, the wider impacts on factors such as equity and the urban economy, and transferability from city to city.

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