INTELLIGENT ROAD PRICING BECAUSE MOBILITY MATTERS

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ABSTRACT
UK road pricing looks set to cover all vehicles on all roads in the UK by 2015 at the latest. The only acceptable technology currently able to take on this challenge appears to be satellite-based. A similar system, already operational in Germany, points the way to how a satellite scheme could work in the UK. This paper takes a comparative view of the German and potential UK scenarios, outlining workable solutions for charge calculation and billing that are acceptable to consumers, government and road charge operators alike.

Road charging is on its way and has been for years. The motivations have changed over time and may continue to do so, but whether driven by the need to reduce and manage congestion, offer more responsible environmental controls or simply replace fuel-related revenues lost as a result of more efficient engines or alternative-fuel vehicles, road charging is definitely on the horizon.

In the end, the precise look and feel of any scheme will be determined by political policy and motivation rather than by technology architects. Its introduction may occur gradually, by region, vehicle-type or some other variable metric, or we may see a more universal and immediate implementation. Either way, the ultimate result will be large scale, directly affecting millions of vehicles in the UK. So how will today's technology cope with the challenges ahead and what can we deduce from existing examples of large-scale road charging schemes?

There is probably only one example in the world of a road charging scheme capable of addressing the ultimate needs of what the Department for Transport seems to be planning for the UK. This example is found in Germany, where all lorries over 12 tonnes are charged for travelling on Germany's 12,000 km of federal motorways. In 2005, in its first year of operation, this scheme invoiced over 23 billion kilometers of driven motorway, raising the German Federal Government's planned revenue target of just under €3 billion for reinvestment in transport infrastructure.

The German scheme is based on satellite technology and has equipped half a million vehicles with on-board units to assist with positioning and distance-based charge calculations. The use of satellite technology is necessary and deliberate. It is the only viable technology for such a large-scale scheme as it requires no road side infrastructure for charging vehicles. Other electronic toll technologies have drawbacks that effectively eliminate them from use. For example, toll plazas, such as those in operation on the M6 Toll or Dartford Crossing, would cause traffic to slow or stop and this is simply too disruptive to traffic flows. A tag and beacon system would have meant the installation of 6,000 to 7,000 gantries for the 12,000 km of motorway alone, an unrealistic scenario. The planning and maintenance implications associated with tag and beacon are ominous and the impact of tens of thousands of gantries cluttering the countryside is colossal, hardly an attractive proposition. An 'invisible' satellite-based scheme was really the only option in Germany and so it is in the UK, where we now anticipate road charging on an even larger scale not yet seen anywhere else in the world.

Figure 1: 'Invisible' road charging with Toll Collect in Germany

So what challenges do UK road charging place upon the satellite technology currently in use in Germany? The simple answer is 'a lot!'. It would be far too simplistic to claim that the same system currently in use in Germany can be translated for use in the UK. There are fundamental differences between the scheme planned for the UK and that in operation in Germany, the most obvious of which is scale. The scale of road charging in the UK is different in a number of important ways, all of which have a significant impact on technology and how it needs to develop to meet the coming needs of the UK. These differences in scale can be broadly categorised to include:

- Number and type of end users
- Size and characteristics of the road network.

NUMBER AND TYPE OF USERS

In Germany, the satellite scheme is scaled to charge 1 – 2 million HGVs > 12t, as specified by the German Government. In the UK, we are looking at over 30 million vehicles for the ultimate scheme. In Germany, on-board equipment is fitted in truck tractor units which are rugged, working environments where function triumphs over form.

The basic technology used in Germany is proven and offers a promising start for any new scheme in the UK. However, UK on-board equipment will be used by private users as well as the commercial sector and will need to work with vehicles ranging from trucks to taxis and pick-ups to Porsches. Responsive customer care, ergonomics, colour options, usability, in-vehicle safety and easy application with the vehicle (as opposed to any hard-wired installation) will all play a more significant role in the planned UK consumer-dominated scheme.

The task of developing more consumer-sensitive on-board equipment is being made easier on a day-by-day basis as consumer demand increases dramatically for other mobile satellite-based applications such as navigation and pay-as-you-drive insurance. These applications also need to address the challenges already highlighted and, to some, extent, will pave the way for effective, consumer-friendly in-vehicle equipment for road charging.

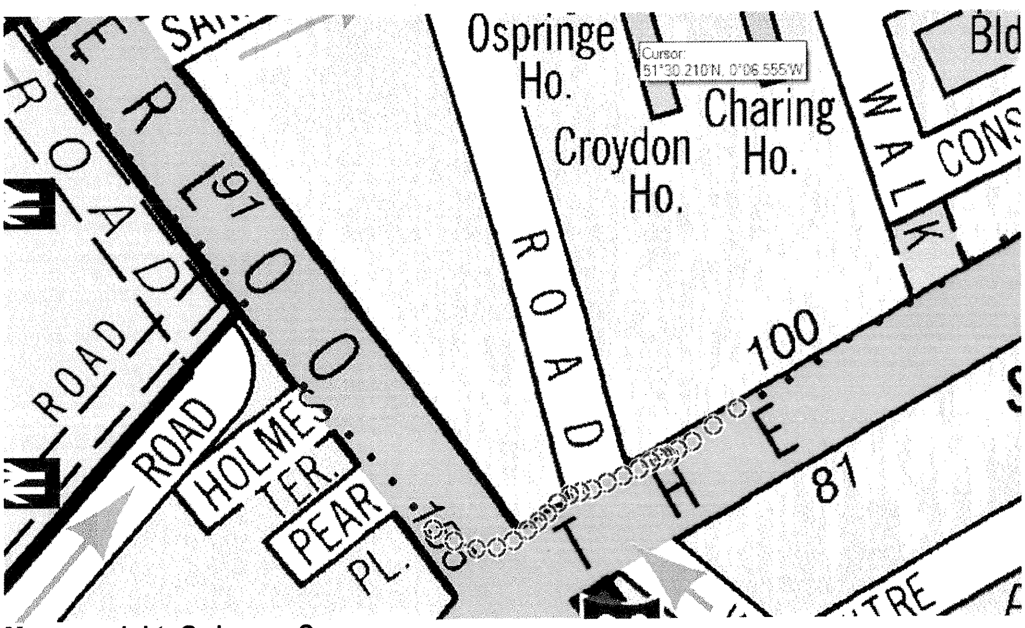
Elements such as data management and communications infrastructure are also impacted by scale but will pose far less of a challenge since the processes to make these work are already in operation in Germany and can be relatively easily adapted to the UK's needs without great impact on the technology. Databases will be larger and communications requirements greater with some cost advantages to the UK Government as higher volumes enable greater bargaining power to reduce charges for transferring data over the existing mobile networks.

SIZE AND CHARACTERISTICS OF THE ROAD NETWORK

The real challenge for any road charging scheme is ensuring customer and consumer confidence. In relation to the road network, this means that the system will have to be trusted in the most challenging of operational environments. For satellite systems, this means crowded urban areas with frequent road junctions, high-rise buildings and underpasses. Although 15% of all charge-segments - amounting to some 375 - on the German motorway network are in urban areas, there is nothing to match the sort of challenging environment posed by a city such as London. Thankfully, London is where the current satellite technology is undergoing most of its UK testing and development.

T-SYSTEMS ROAD-CHARGE TESTING IN LONDON

This following illustration shows a test drive in London with a vehicle equipped with a T-Systems Satellic road charging unit. In this example, the GPS signal (represented by blue markers) was deliberately degraded while the vehicle turned onto a new road. The route data was then reprocessed using dead-reckoning sensors (denoted by the red circles) to provide position fixes in the absence of GPS. The close alignment of blue and red markers demonstrates highly accurate route tracing.



Map copyright: Ordnance Survey

Figure 2: GPS route tracking in London

Digital maps go a long way to predicting the whereabouts of most challenges such as under-passes and tunnels and so these can be quite easily accommodated by a satellite-based road charging scheme. Also, the sensitivity of satellite positioning is increasing on almost a quarterly basis and supporting sensor technology is also being improved to refine positioning and route-tracking to ever more accurate levels. And, where route segments are not properly recorded by satellite-based positioning, map matching and billing software are being refined to produce highly-accurate, consumer-orientated solutions for road charging in even the most hostile environments. So when occasional route segments are not recorded beyond reasonable doubt, billing software can take over to ensure least-cost routing for the missing or doubtful segments, thus ensuring that the consumer is not penalised for a system failure.

Charge calculation and billing solutions, whilst following the same broad procedures and principals of the Toll Collect system, will need to be adapted to meet important new criteria. These will include a much larger user base with both commercial and consumer concerns, as well as the more complex road network with a greater proportion of urban area and quite probably sub-divided into road type.

As well as varying charges by road type, vehicle type and time of day, charges may apply per km travelled, or by duration in a charge zone/cordon or by the fact of simply crossing into a charge zone (as currently happens in London). Charge calculation involves highly compressed route information being streamed for all vehicles to a central system in near-real-time. This data is securely encrypted with a key unique to each particular OBU/user, to ensure privacy of the data both when stored and during transmission.

The data is retained by the central system and only needs to be retained sufficiently long enough to support evidential validation of the charge in the event of a billing challenge by the user (150 days in the case of Toll Collect). Access to the data is limited to only privileged users within the central system's enforcement team with appropriate access rights.

This data may also be used by transport planners to assess traffic flow in near-real-time, in addition to providing detailed historical data (as routes may be archived and stored for more than the enforcement period). In this case, the data may be disassociated from the OBU ID/VRM or user account such that it is anonymous.

Impressively, current evidence on billing accuracy, queries and repayment rates is compelling. For example, at Toll Collect, over 99.9% of revenues from all bills and fines are collected. Only 0.06% of bills are queried, and of the €4,007,246,069[1] revenues collected, only €122,592 has had to be refunded.

While there are technological challenges to the introduction of road charging in the UK, they are clearly identifiable. Development is already well underway to meet a great many of them from refining charge accuracy in difficult, urban environments to the form and colour of in-vehicle equipment. While all this work proceeds, questions still remain as to the true motivation (or motivations) for road charging in the UK. Is it simply to be a congestion management tool or are there also environmental and tax revenue drivers? Answering this may still prove the biggest challenge of all.

[1] 1st January 2005 – 22nd May 2006

KEEPING ROAD USER CHARGING SIMPLE

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ABSTRACT

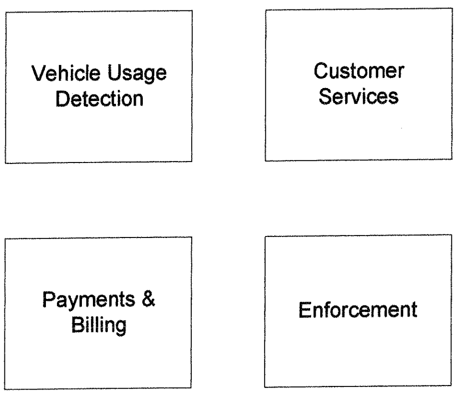
Many administrations around the world are now seriously considering road user charging. In this paper I answer the question "How can a scheme have a higher chance of success by design?". My premise is that the design of the scheme has a high impact on the choice of technology required, the cost of implementation and also on public acceptability and usability. Deloitte have worked with many clients around the world, helping them with feasibility studies, implementation and operation of road user charging schemes. As a result we have accumulated and shared much experience of what works and what doesn't. In summary my advice is that simple is best and this paper explains what makes a solution simple.

INTRODUCTION

Implementing any scheme to tackle congestion is a complex process with many political, legal and engineering challenges. Any scheme must be acceptable to the public and able to deliver its congestion and financial targets. Taking a scheme through from concept to implementation is not going to be easy, however the probability of successfully implementing the necessary systems is improved if the scheme design and policies are tempered by the realities of the technologies available. This paper looks briefly at the characteristics of the technologies commonly considered for road user charging and then the types of scheme design which could be implemented. It then looks at the impact which certain scheme features have on the technology and processes required. The objective is to give the reader an understanding of how to evaluate policy decisions to achieve a simpler and thus better value solution.

RUC COMPONENTS

From a systems perspective any Road User Charging (RUC) system needs the following components:



- Systems for detecting an individuals usage of the scheme.
- Systems for payments, billing and/or account management.
- Customer Services systems for registration, enquiry and/or complaint handling.
- Enforcement systems to chase those who fail to comply.

In terms of technology, billing and Customer Relationship Management (CRM) systems are reasonably well understood with the requirements for RUC similar to those of many large scale customer facing applications. Billing for RUC is similar in complexity to telecoms billing, the challenge is getting accurate usage data, not in applying a tariff or handling accounts. For the CRM system the objective is to minimise the cost of service either by reducing the service need or by providing self service via efficient channels. I.e. For CRM the issue is not delivering functionality but avoiding scheme designs which generate excessive demand for the expensive channels.

Enforcement systems are also relatively common with obvious parallels to other traffic related offences such as speeding and parking. It is worth noting that the volume of enforcement work is under the control of the scheme's authority as there is always an option to adjust how rigorously the scheme is enforced. There is also a relationship between the size of any penalty and the chance of being caught which will drive user compliance.

The vehicle detection requirement is more specialist and will probably require the use of one or more of Toll plaza/barriers, Automatic Number Plate Recognition (ANPR), Tag & Beacon and/or Global Navigation Satellite System (GNSS) based systems. These technologies are discussed briefly in the following section.

VEHICLE USAGE AND DETECTION TECHNOLOGIES

The following table provides a quick overview of the key technologies available and commonly used for detecting vehicle usage. Note that these technologies are not mutually exclusive and it is common to consider hybrid solutions which use different technologies for different type of user within the same scheme.

Technology	Basic Description	Key Advantages	Key Disadvantages
Toll Plaza/Barrier	Either manned our automated physical barrier. If the user doesn't pay they are not allowed to pass or are otherwise captured.	Easy for users to be informed and understand when and how much to pay. Relatively simple and proven technology.	Inhibits free flow of traffic. Requires physical space.
ANPR	Camera based systems with image processing to identify and read vehicle number plates.	In vehicle equipment is not required. (All vehicles have licence plates) Images can provide evidence for enforcement as well as detection for charging.	Requires roadside infrastructure. Reads are not 100% accurate so checking processes maybe required. Plates can be missed. No clear interaction at point of detection to inform customer.
Tag and beacon	In vehicle tags communicate with roadside beacons. Commonly uses Dedicated Short Range Communication (DSRC) microwave frequency but may also use Infra Red or Radio frequencies.	Accuracy of tag reads means that manual processing of detection data is minimised. Relatively inexpensive in-vehicle equipment cost (of the order £5 - £20 per vehicle).	Requires correctly fitted tag and roadside equipment. Tags can be missed. Positioning of beacon equipment for correct operation constrains site layout. Still requires cameras for enforcement.
GNSS	In vehicle equipment uses satellite signals to calculate position and vector of travel information. This then requires matching to map information to identify the route travelled.	Can work on all roads without the need for roadside infrastructure. Potential flexibility to support widest variety of charging policies.	Accuracy dependent on map matching or other processing techniques of raw position data. Relatively expensive in-vehicle equipment required (of the order £100-£500 per vehicle). Still requires cameras for enforcement.

CHARGING POLICY TYPES

Schemes can be broken down loosely into three types: area charge; cordon charge and distance based. These types are briefly described below:

Charging Policy	Basic Description	Key Advantages	Key Disadvantages
Area	Vehicles are charged a flat fee for travelling within a specific zone. E.g. London.	Can be easy for users to understand. .	Can be seen as unfair as light users potentially charged the same as heavy users.

Charging Policy	Basic Description	Key Advantages	Key Disadvantages
Cordon	Vehicles are charged for passing specific charge points. E.g. Stockholm. Road segment charges as used on many toll roads also operate in this way.	Can give finer pricing control as more charging events are generated.	May encourage more journeys within the zone as these have no charge. May be complex for user to understand how much they should pay.
Distance Based	Vehicles are charged based on the distance travelled. E.g. Lorry Road User Charge in Germany.	Can target vehicles which contribute most to congestion.	Potentially complex for users to understand. Privacy concerns of vehicles being tracked.

Each of these charging policies can have further variations with different tariffs based on combinations of time of day, direction of travel, road type, vehicle characteristics (emissions categories, If the vehicle has a trailer, etc) and vehicle class (Heavy goods vehicle, car, motor bike, etc). Each variation may enable targeting of the charge at specific vehicles but at the added complexity for the user who needs to know how much they should pay and the operator who must understand how to register users, calculate charges and enforce contraventions of the charging policy adopted.

HOW TO ACHIEVE BEST VALUE

To achieve best value the factors which must be balanced are the implementation costs, the operating costs, the understanding and acceptability by users and achieving the desired change in the pattern of vehicle usage. The following topics give a brief understanding of some of the key points it is advisable to consider in trying to identify the correct balance for a specific scheme.

GEOGRAPHY OF SCHEME AREA

The implementation costs for detection equipment is obviously greatly influenced by the number of physical roadside sites required. This in turn is mostly dependent on the geography of the scheme area. Comparing London and Stockholm the geography has an enormous impact with just 18 sites required for the entry and exit points of the Stockholm zone vs near 200 for London. Whilst geography is somewhat unalterable you may have choices about which roads or physical features are used to define the boundaries with site numbers varying dependent on these choices.

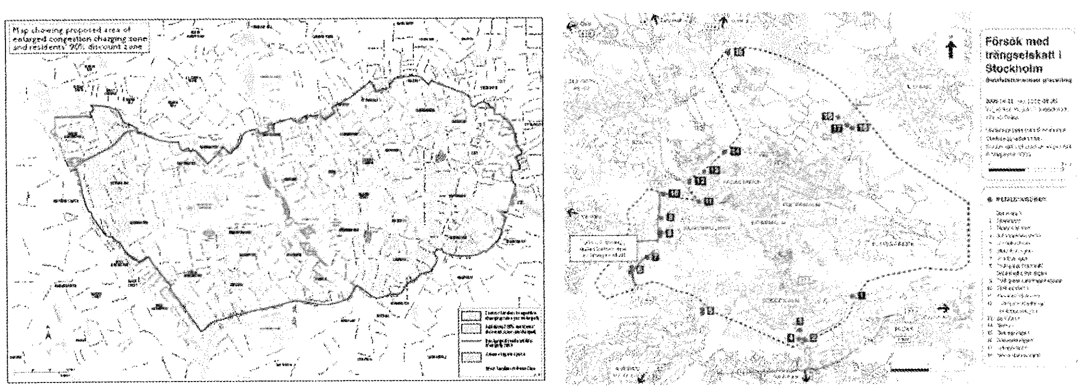


Figure 1 – Maps of London and Stockholm congestion charge zones

Geography is also relevant to the decision between Area and Cordon based charging. For an Area charge sufficient infrastructure is needed to capture usage within the area as well as the entry/exit point sites as needed for a Cordon charge. Thus an Area charge is likely to require more sites, although there are further factors which will also influence the choice.

The size of the scheme area is also relevant. Cordons don't scale well over large areas as more vehicle movements are included within the Cordon and are thus not impacted. Whilst Area charges do in theory capture these vehicles the number of sites must increase if you want reasonable probability of capture and fairness issues increase with the potential difference between short journeys and long journeys increasing. In both cases you can of course implement multiple Cordons or Areas. For large geographical areas GNSS based systems start to look more attractive allowing more flexible charging and potentially negating the need for roadside equipment but the cost of onboard equipment must reduce significantly before it is economically viable for large numbers of vehicles.

The other restrictions from geography are consideration of streetscape. Gantries and toll plazas maybe acceptable on major roads but less so in urban areas and outside historic buildings.

Figure 2 – Examples of gantries in Stockholm and Singapore.

PROFILE OF USAGE

The profile of usage will have a large impact on the cost of servicing the schemes users and should therefore be considered when defining policies. There is often a perception that commuters make up the bulk of journeys within cities but if there is a reasonable public transport network and a congestion issue it is likely that many regular commuters will already have switched from their cars. Thus it is probable that whilst there will be a core of regular users there will also be a large percentage of users who visit very infrequently.

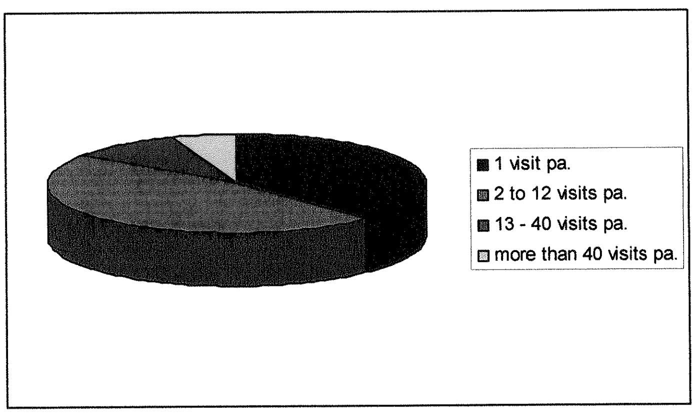


Figure 3 – Example frequency of usage profile.

This tail is important as without suitable consideration these users can cost more to serve than the charges they pay. It is the infrequent users who generate enquiries and complaints if it is not obvious to them how, when and how much they must pay to comply.

MINIMISING SERVICE COSTS

The cost of serving the users of a scheme is the multiple of the frequency of communication and the cost of response so it is advantageous to minimise both. E.g. If there is a reason why customers would frequently call a call centre then the cost to serve will increase so it is worth designing out the reason and/or providing a lower cost route for the required service.

The most used service within an RUC system is likely to be for payment. The methods of payment allowed will have a large impact on the cost of this service. This includes the actual payment method (E.g. credit card, cheque, cash, etc), also the available channels (E.g. web, call centres, retail outlets, etc) and the method used to charge (E.g. charge on detection, user's responsibility to make appropriate payments, pre/post payment, etc). The objective is to set scheme charging policies and methods to maximise the use of electronic payment channels and customer self service. But this is non trivial as there is not a one size fits all answer and there will be a clear difference between the cost effective solution for frequent users compared with that for infrequent users.

PAYMENTS AND BILLING

To setup an automated payment arrangement some form of registration process will be required. There will also be a need for customer services to resolve billing enquiries and any errors on accounts. Thus the cost to serve the customer is only reduced if the costs of these processes are outweighed by the saving in taking the payments due via another mechanism. The following graph illustrates this using some simple assumptions (Registration and resolving billing enquiries each take customer services 10 minutes and taking a single payment takes 2 minutes with customer service time valued at £1 per minute. The impact of billing accuracy at 95%, 99% and 99.9% are compared).

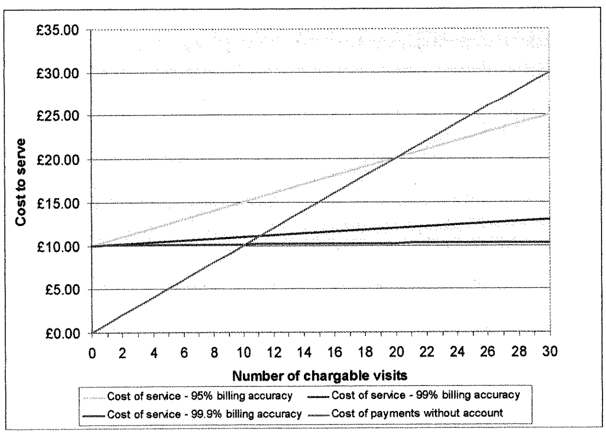


Figure 4 – Illustrative cost to serve by number of visits and billing accuracy.

The model is very simplistic, and it is unlikely you would ever consider issuing bills with the high levels of inaccuracy indicated, however the graph starts to show how various factors interact to give a predicted cost to serve by frequency if use. For example increasing billing accuracy or reducing the cost of resolving billing issues would both reduce the point at which it becomes cost effective to register users for accounts. Likewise reducing the cost of taking payments without accounts would increase the point. Similarly increasing or reducing the cost of registration moves the point up and down.

Looking at typical approaches to minimising the operational costs of taking payments it is possible to see the potential for both positive and negative consequences:

Approach	Potential positive impact	Potential negative impact
Customers required to purchase appropriate product for their usage. Penalty charges are applied to any vehicle which does not have a valid product for any usage detected.	Vehicle detection only required for enforcement so no billing accuracy issues. Maintains a clear linkage between the journey and the payment for the scheme user. I.e. They must make a conscious choice to pay for the journey.	Customer confusion creates queries and complaints unless products are simple. If customer can ask how much they owe then detection accuracy becomes an issue. Can be perceived as unfair and result in penalties to those who forget or don't know how to pay.
Customers register for accounts and maintain a pre-pay balance. (similar to mobile phone top up)	Automated billing and top up can reduced the cost of taking payments. Potential for more complex pricing and thus more targeted impact on congestion. More convenient for frequent users. Customers can't forget to pay.	Registration costs maybe higher than payment service costs for infrequent users (as discussed above). Additional Customer Service cost to resolve problems for users whose top ups fail for some reason (e.g. credit card expiry, insufficient funds, etc). Accuracy of billing exposed to customer resulting in revenue loss and/or billing enquiries. Customers not likely to want to maintain a significant positive account balance leading to many small top ups each incurring a transaction cost.
Customers register for charging accounts and are then required to settle account balances regularly in arrears. (similar to mobile phone contract)	Automated billing can reduce cost of taking payments. Potential for more complex pricing and thus more targeted impact on congestion. Reduced number of billing transactions (I.e. One bill per month, one higher value payment) Customer convenience.	Registration costs maybe higher than payment service costs for infrequent users. Customer service cost for debt chasing. (Note this may result in many small debts costing more to collect than the value owed) Accuracy of billing exposed to customer resulting in revenue loss and/or billing enquiries. Potentially requires compliance with additional financial services regulation to provide customers with credit.

The key to gaining a cost saving through account type payment is billing accuracy. If the bills are not accurate enough either revenue is lost or Customer Services will be swamped with complaints and enquiries costing more effort to resolve than taking individual daily payments.

BILLING ACCURACY

The accuracy of billing for an RUC user is mostly dependent on the accuracy of the usage detections. This in turn is dependent on the characteristics of the equipment used but charging policies may also dramatically increase or decrease the billing accuracy and/or the effort required to produce accurate bills.

First consider an ANPR solution with a vehicle journey through a charged zone as below.

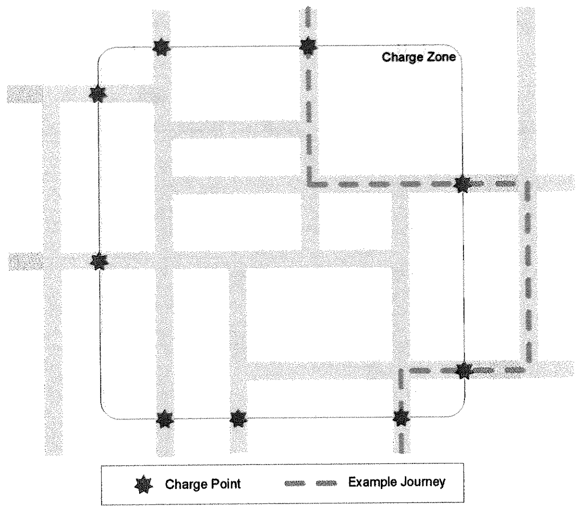


Figure 5 – Example journey through a charge zone

In the journey the vehicle passes 4 detection points. If these detection points used ANPR technology which had 80% chance of generating a correct read then the probability of being correctly detected by at least one of the 4 sites is $(1-(0.2)^4)$ = 99.84%. The probability of being detected correctly by all of the 4 sites is $(0.8)^4$ = 40.96% (both assuming no systematic reason for error). Thus if the policy was a fixed amount for travel in the zone (an Area charge) then it is very likely the bill for this journey would be generated correctly, as only one detection is needed to ensure this. Conversely if the policy was to charge for each detection point passed (a type of Cordon) then the chance of a correct bill is just 4 in 10 with the user likely to be undercharged.

In both cases misreads still may cause the wrong person to be charged or issued with a penalty so these can't be ignored. Each misread may match with another valid plate either with or without an account. For the Area type charge you could adopt a policy of checking any charge supported by only a single read or a worst case of checking one image for each charge. For the Cordon the number of checks can not be reduced in this way and the worse case is that every image needs checking. Thus for an ANPR account based payment the Area policy is expected to result in less image checks being required and/or less billing errors. Note that there is no difference between processing penalties for either scheme as any policy of checking images for penalty charge candidates would be the same for both.

The above assumes that manual checking is the only method for correcting ANPR errors but identifying and correcting a proportion of ANPR misreads can be performed electronically without manual checks. Algorithms can be designed around the patterns of errors produced by the equipment being used to either flag or adjust likely incorrect reads. For example if you have seen plate "ABC123" twice and "A8C123" once and your equipment is known to misread "B" as "8" then you can be fairly confident in adjusting the "8" to "B". Another technique for flagging possible errors is to pass images through second ANPR and check cases where the interpretations disagree. The aim of any such checks is to reduce the quantity of manual checks or direct manual effort at the most likely errors.

The cost of image checking in such scenarios is often used as a justification for tag and beacon based vehicle detection technologies. But in making the decision you need to calculate the cost of the manual checking process as this maybe less than the costs of deploying and operating the tag and beacon solution. A simple comparison of the cost of manual checks vs the cost of supplying a tag is shown below. Tags can have a reasonably long life 5 years plus and with a cost of roughly £10 gives an annual cost of about £2. A single checker should complete 3000 checks per day (5-10 seconds per check) with a cost of employment around £45,000 gives a rough cost per check of 7.5p.

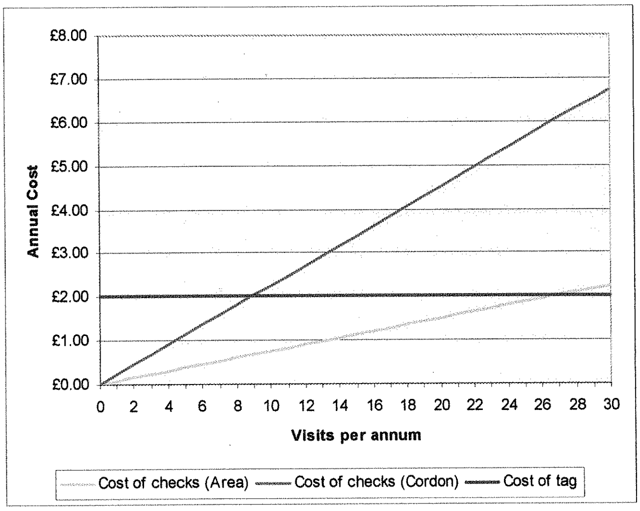


Figure 6 - Cost of supply and maintenance of a tag vs the cost of manual checking.

The example assumes that an average Cordon user crosses the boundary 3 times each time they visit and that each crossing incurs a charge. Potentially the average maybe more or less but it will always be higher than the area charge. The point to note though is that tags are not cost effective for low frequency users and for an area charge, at least, the point at which they become effective is reasonably high.

CONCLUSIONS

The aim of this paper was to give the reader an understanding of the characteristics of road user charging technologies and to show how the charging policies adopted for a scheme can either best use the technologies strengths or, if bad choices are made, expose its weaknesses. In conclusion, barriers and toll plazas are not viable options for most Road User Charging purposes because of both the physical space they require and their impact on the free flow of traffic. Satellite systems are prohibitively expensive for unless the scheme impacts a relatively small number of users or covers a large physical area (E.g. National lorry user charges). This leaves ANPR and Tag based options for city and other limited geography or route schemes. Here the art is balancing the issues of ANPR accuracy against charging policy. The practicality of ANPR only solutions diminish as the number of charging events per user increases however the cost of Tag based solutions and handling the infrequent users must be balanced against the scheme objectives as the more complex options will inevitably cost more to implement, operate and enforce.

REFERENCES

Maps and details of London and Stockholm schemes can be found at the following locations:

http://www.london.gov.uk/mayor/congest/index.jsp
http://www.stockholmsforsoket.se/

ROAD PRICING WITH A FUNDAMENTAL APPROACH – CHARGING BY MOBILE PHONE USE

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ABSTRACT

As the percentage of mobile phone usage increases in developed countries, it is no surprise that almost everyone has at least one mobile phone at his/her own convenience of communication. At the same time, road users in these countries face continued congestions and delays. Road pricing is frequently proposed to relieve the traffic demands, but technologies supporting this policy of charging congestion are very expensive. Enforcing 100% vehicles to pay the congestion charge will cost government and users a big fortune. However, a loose way to charge road usage may save the effort and expense for the entire community. The proposed mobile phone approach is to use so-called roaming charging concept that anyone who leaves his/her base area will encounter service charges. This study examines the possibility of road pricing could be done by tracking mobile phone movement, and discusses the issues related to fairness and their technical feasibility.

KEYWORDS: Mobile Phone, Roaming Charges, Congestion Charge, Road Pricing

MOBILE PHONE USAGE

As recent wireless technologies are rapidly developed, having a mobile phone is no longer a symbol of wealthy. Instead, people enjoy the mobile communication and its affordable price. Under the server competition in the telecommunication industry, some telecommunication companies even give out free mobile phones, claiming that they only charge customer the services. Thus, this trend provides a good opportunity for transportation agencies to execute road pricing policy by adding extra charges for mobile phone services.

In the early days of mobile phone services when the base stations were established by different mobile phone carriers, roaming charges were usually applied to people who used their mobile phones outside home-based area. Under the transportation concerns, a trip to out-of-home areas must require certain modes of transportation, meaning that charging by out-of-home-area mobile phone usage could result in similar effects of road pricing. Figures 1 to 3 show some basic concepts of congestion charging. In Figure 1, when travel within the neighboring areas, there is no service charges applied to the users. Only when a user leaves for other traffic zone shown in Figures 2 and 3, the congestion charge then applies to the user, according to the rule of road pricing.

Road pricing and electronic toll collection lessons have been learned in many countries, particularly for the full-scale deployment. The dilemma is to pay additional price for saving vehicle travel time and decreasing chance of stop-and-go traffic. Some road users would like to select the conventional way that is pay at booth. At least, there is no payment for the on-board-unit and the fine for improper operations, such as insufficient deposit or device malfunction. Table 1 shows the differences between the traditional device-based congestion charges and the congestion charges by mobile phone use.

Table 1 – Comparisons between the Traditional On-Board-Unit and Mobile Approach

	Traditional with devices	Charged by mobile phone uses
Device Costs	High to moderate	Low to free
Construction	Lengthy	Ready to use
Clearinghouse	Required / Simple	Required / Complicated
Payment	Additional accounts	One mobile phone account
Group Resolution	High	Low
Standard	DSRC/Infrared	Mobile Phone
User Friendly	Some training	Transparent
Scale	Partial road/area	Full
Landscaping Impact	Gantries/Equipments/Signs	Limited to base station antennas
Application Speed	Up to 150 KPH	Unlimited (detected by zones)
Enforcement Rate	Above 99%	Estimated 84% (Mobile Phone Users)

Arguments may come from the possibility of 100% mobile phone ownership or multiple phones ownership that creates the situation of unfair congestion charges. This consequence is actually as same as charging by other methods where broken charging tags, dirty license plates, or adverse weather could similarly deter road pricing policy. Thus, users may have a chance escaping from the congestion charges. Some reports state that mobile phones equipped on-board GPS could be precisely charged by distance traveled, but under some conditions, such as phones in the pocket, inside a vehicle, inside a tunnel and inside a parking ramp, users would never rely on their GPS devices for getting accurate positions. In addition, extra costs for the GPS phone sets and a very complicated process involving in computing locations and associated congestion charges would be nightmares for every telecommunication companies.

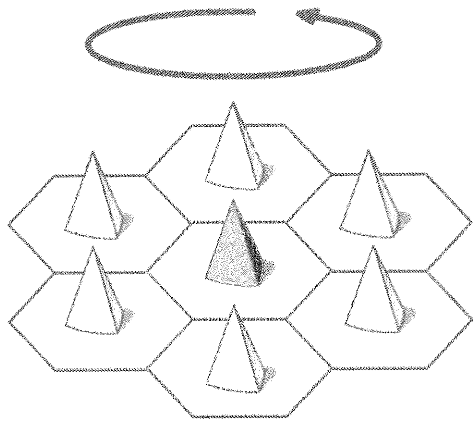

Figure 1 - Travel within neighboring zones (without congestion charges)

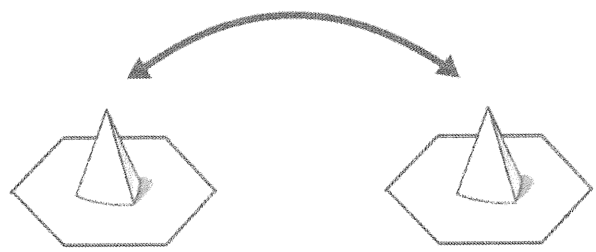

Figure 2 - Traveling from one to another zones (charging by number of alternations)

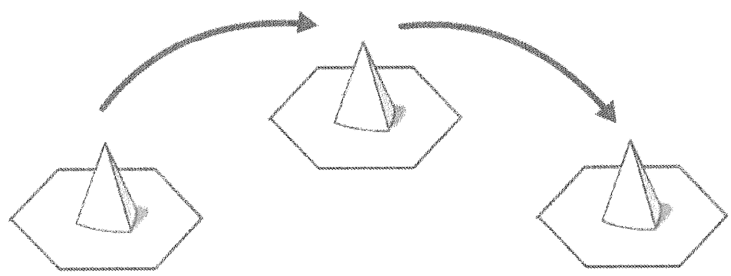

Figure 3 - Traveling 3 zones (charging two links)

CHARGING MECHANISM

The charging mechanism using the location of mobile phones should have the following steps. First, the authority should divide charging zones according to transportation control schemes. This may involve coordination of transportation agencies and telecommunication companies. Usually, the telecommunication representatives would care less zoning problem, but care more about the quality of communication. This may call for efforts for re-zoning. After separating base stations into several zones, a data clearing house system should be established and used to perform post-travel fare allocation for the congesting charges. All charges could be subsequently added into the user's telephone bill, which completes the process of congestion charging. Figures 4 and 5 show the charging mechanism.

ACCOUNT: WEN JING HUANG
ID: 0921912785, 0921912787 ← Phones in the Group
GROUP ID: 10602 ← Base Zone
RATE: N3
PRINTING DATE: 2006.08.17

Congestion Charges

CONGESTION CHARGES DETAILS

ITEM	DATE	TIME	ZONES	RATE	CHARGES	T
1	0807	0652	10602-10523	2	0.50	2
2	0807	0713	10523-10421	2	0.50	2
3	0807	0720	10433-10055	3	0.75	2
4	0807	0745	10002-11135	1	0.25	2

Time Entering Congestion Charging — Travel Zones — Charging Rate — Phones in the Group

Figure 4 – Sample of Congestion Charging Bill

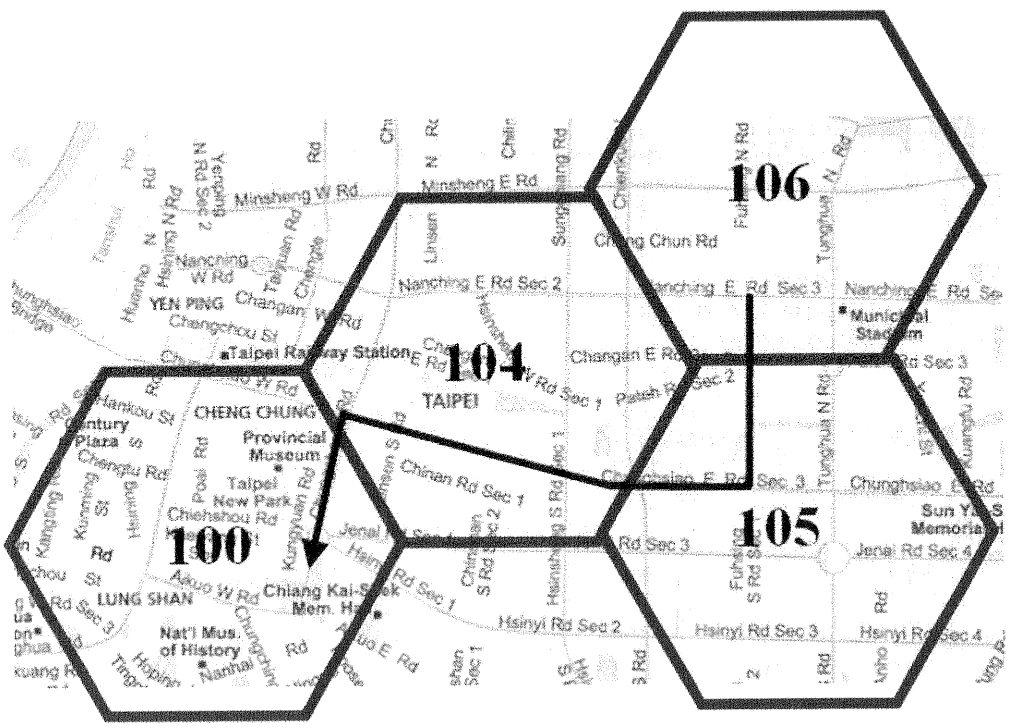

Figure 5 – Charging by Traveling Zones

In order to decrease the chance of mistaken charges, all users should register a home-base zone. All mobile phone signals at the registered home-base zone and its neighboring zones should waive from congestion charges, because there may be simply no significant travel generated under such circumstance. Movement from one zone to another zone could subject a congestion charge, which may be determined by a pre-set rate table.

AVOIDING LOOPHOLES

Like other methods of charging congestion, there are always tricks to go around. For this congestion charge by mobile phone usage, users may purchase multiple phones or Subscriber Identity Module (SIM) cards to use at different locations for getting away charging. However, if the congestion charge is based on a wider group that almost covers every mobile phone users, swapping phones and SIM cards may only happen to a small number of people. The negative effects would be minimal or ignored. Nevertheless, the inconvenience of maintaining multiple devices or SIM cards to avoid charges is definitely non-economical. Additional, who wants to make other people confused by applying the multiple telephone numbers strategy? Simply, this strategy is contradictory to the goal of improving convenience of mobile phone usage and only limited people are interested.

For the people having multiple phones for performing their business, they may simply shut down their mobile phones while travel, or register as multiple phone users to avoid overcharging congestion. As long as he/she has registered as multiple phone users, the multiple phones must travel together within a area at the same time. The multiple phone users are only subject to congestion charge one time only.

Other argument may involve switching on and off during the trip. This may create invisible trips, but one who can sacrifice the convenience of mobile phones may have a good excuse from being charged by the congestion. Eventually, when he/she switches on his/her mobile phone in different areas, the congestion charge automatically be added on his/her phone bill. Of course, people without mobile phone can never be a target for congestion charge. These people will be treated as non-peak travelers in the metropolitan area.

There may be some shortcomings using mobile phone charge method including the difficulty in distinguishing public transportation users and non-public transportation users. Fortunately, this can be adjusted by heavy subsidizing the public transportation systems by using the pooled funds of the congestion charges. Thus, the public transportation riders can find themselves a much cheaper trip even though they have paid congestion charges.

Critics may argue that combining smart phone and congestion charge would result in fewer mobile phone users. This may not be true. The additional charges for fuel taxes have effects on reducing traffic demands, but never eliminate cars from the traffic. The difference between charging fuel tax and charging congestion would be the time and route sensitivity issues. If collect congestion charge properly, people travel to other area at the peak hours would be reduced.

PEOPLE INVOLVING IN TRANSPORTATION SERVICES

Some people involving in transportation services, such as bus and taxi drivers, delivery drivers, public workers, and services vehicle drivers may frequently travel from one place to another place. These people could register a flat-rate congestion charge and they may obtain reimbursement from his/her employers for having to pay extra congestion charges.

Table 2 illustrates the problems and remedies associated with charging congestion by mobile phone uses. Although there are still some road users cannot be charged by the approach of mobile phone approach, the estimated potential charge rate is about 84 percent of the total road users. Thus, the mobile phone can be considered as a useful tool to help traffic management agencies to collect proper congestion charge.

Table 2 – Problems and Remedies for Charging Congestion by Mobile Phone Uses

	Problems	Remedy
People in public service (Taxi, Bus operators)	Extra charge by providing services	Flat rate
Public transportation riders	Paid as private car users	Heavy subsidy for public transportation
Multiple SIM card of mobile phone users	Pay double	Group multiple phone and must travel at same time
Switch on-and-off users	Unable to Charge	Trace mobile locations
Car pooling users	Multiple charges	Apply for group usages

FUTURE APPLICATIONS

In the future, vehicles equip communication devices which could be mobile phone capable, could further provide accurate and easy congestion charges. In addition, mobile phone base stations can be identified along different routes to collected different congestion charges. Until then, either relying on expensive charging systems or a cheap and slack charging system using mobile phones can satisfy the goal of the transportation agencies.

SUMMARY

Although studies have not proven the relationship between vehicle usage and mobile phone usage, the high percentage of mobile phone users reveals potential of charging congestion by using such technology. Disregarding to expensive congestion charge systems, such as tagging, license plate recognition, and on-board device installation, the mobile phone charge system, without requiring users to purchase additional devices or create additional accounts, would be very simple and quick solution for collecting congestion charges. The only cost is to build a simple clearinghouse system that can process all roaming charges due to travel made by the mobile phone users.

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Intelligent Satellite-Based Road Pricing
The Thin and FAT Client concept in the GNSS environment

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Abstract

Deploying Road Pricing systems is one possible way to relieve regional transportation problems by using these systems as a tool to manage demand and additionally create funds for maintaining, preserving and improving transportation infrastructure. The choice of the right charging technology is still the ultimate question. As well the decision for the "right scheme" has to be taken into consideration as well. The field trial that is referred to is effected in an environment that is clearly determined for GNSS-based systems. It will show integrity and accuracy of GNSS tolling applications.

Combining the knowledge from a 400-participants 1 year+ field trial, with the know-how gathered in various bids, this trial uses a two-way approach with a "Thin Client Concept" and a "Fat Client Concept". Even the issue of interoperability has been addressed. Thus, the technology proof might lead to a technology shift.

Aim of the Pilot Project

The pilot project shall show the feasibility, the advantages and possible future applications within the market they are tested in.

In order to proof the readiness of GNSS based toll systems, a "Thin Client" as well as a "Fat Client" have been installed into each On Board Unit (OBU). Thus, the positive versus the negative arguments of both systems can be easily evaluated.

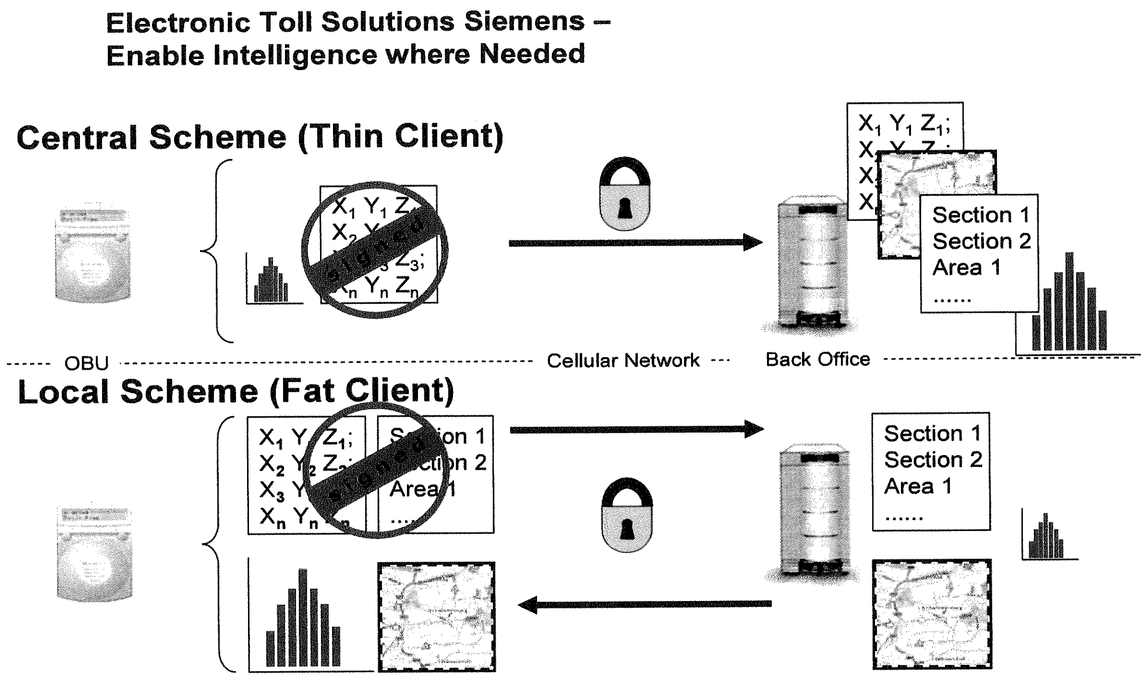
General System Overview

The GNSS-based toll solution offers to users as well as to the operator the following features designed for road pricing:

- On Board Unit
- Central Management System (CMS) consisting of:
    - Interface to a GSM service provider
    - Application Server (e.g. Toll Calculation System, Accounting, Billing) with central control mechanism
    - Database Server
    - Web Server with internet connection
- Support for participants (Call Centre)
- Handling of Road tariff table and Toll road data

Centralised (Thin Client) + local (Fat Client) processing

The toll calculation can be done either centralised at the back-office or locally within the OBU. Local processing reduces data volume to be transferred over the GSM network while centralized processing simplifies handling of toll road data and tariff structures. All existing components that are mentioned here, especially the OBU, are designed to support both system types. The field trial aims at both concepts to figure out the positive and negative aspects of each approach.

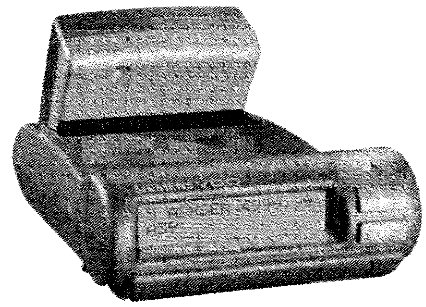


OBU

The Siemens OBU has shown proven reliability in the German Heavy Vehicles Tolling System and in the Seattle Trial in Washington, USA. Main modules of the OBU are a GPS receiver, a GSM/GPRS module for communication, a gyroscope module, a main processor with storage capacity and different interfaces for vehicle integration, antennae and DSRC. The OBU has the following characteristics:

- Storage of specific information within the unit itself
  - Collected data set (User identification, GPS coordinates, Timestamp etc.)
  - Toll road data (local scheme only)
  - Road tariff tables (local scheme only)
  - Trip data
- Reliable under all weather conditions
- Display
- Parameters to be set for (e.g.)
  - tracking time intervals,
  - storage capacity for non-toll trips,
  - threshold for communication,
  - vehicle class

- Integrated **SIM Card** Reader (for security card)
- **GPS** receiver
- Integrated **GPRS-module**
- **DSRC module**
- Integrated **gyroscope**
- 2 buttons
- **Display** (2*16 characters)
- 2 CAN interfaces
- Connection to speed signal



OBU 1372

Data Transfer

The primary data communication link between the OBU and the Central Management System (CMS) is a GSM communication channel. Within this channel, three different services are supported by the OBU as well as by the CMS: GPRS, BS26 and SMS. The availability of services in different regions leads to the decision which type will be used. 100% GSM coverage is not necessarily needed to guarantee data integrity because of the alternative services supported and the storage capacity contained in the OBU where data will be stored until transmission. Transmission can be triggered by different events (e.g. time interval lapsing, reaching a defined number of data entries etc.).

Toll Calculation System

The toll calculation system (TCS) matches geospatial data that is collected by the OBU with a roadway facility map (route waypoints) and assigns a toll value for in-vehicle display. The same information is used for account billing purposes. The TCS is either embedded in the OBU or part of the Back-Office System. The TCS incorporates a map-base of sufficient accuracy that the location of the vehicle will not be ambiguous as related to tolling on segments. The TCS also performs a geo-coding function on the processed GPS signal to provide the route identified for tolled segments. Tolled links are tracked by segments; non tolled links are tracked using GPS coordinates as well as out-of-region links.

Central Management System

Back-office applications for tolling are classified in system/user specific software which has to be developed according to user requirements and off-the-shelf applications like Data Base Management Systems as part of accounting, billing and clearing packages as well as web packages or call centre solutions. The latter only have to be adapted to project specific needs but usually have a high percentage of re-use modules. Siemens uses proven components from Norway, Austria and other countries especially from applications where the user interface has been a proven success.

Interoperability

The 5.8 GHz built-in DSRC-module in the On Board Unit detects the DSRC gantries mounted across the toll road. Therefore, the detected location from the GNSS application can be mirrored with that of the DSRC application. Furthermore, the On Board Unit supports with this feature interoperability and a possible technology shift.

Outlook

The field trial will show future opportunities or limitations for applying GNSS-based tolling systems in the respective country. If it proofs to be economically more advantageous than DSRC, then nothing hinders a large scale implementation.

Results

The Trial has been running from November 2005 until March 2006. Results will be available in the second half of 2006 and will be presented at the World Congress London 2006.

ROAD USER CHARGE FOR FINLAND – PRESTUDY

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Abstract
The Pre-study for Road User Charging in Finland was commissioned by the Finnish Ministry of Transport and Communication and the Road Administration in the autumn 2005. Finland does not yet apply road user charges (expect general vehicle taxes). However, the environment is changing as other countries apply or plan to introduce RUC especially for Heavy Goods Vehicles and European Transport Policy favours taxation of road use rather than of vehicle taxation. The main results of the pre-study are a general overview on the general principles and constraints for RUC, the existing and planned RUC-systems in various European countries and the starting points and possibilities for Finland.

Keywords
Road user charging, Finland

Introduction

The pre-study on Road User Charges (RUC) in Finland includes overviews of
- the Finnish situation regarding road network, traffic volumes, taxation of traffic and road financing
- legal constraints, general principles and technical solutions for RUC
- RUC in European countries
- RUC opportunities for Finland

The pre-study was commissioned by the Finnish Ministry of Transport and Communication and the Road Administration in the autumn 2005. The work was done by an international consortium led by Traficon Ltd and consisting of Rapp Trans, VTT, JT-Con, TÜV InterTraffic and Sweco VBB.

Overview

Finland

Finland is located in the north-east of Europe and covers an area of 338'145 km^2. Its length is 1'160 km from the south to the north and width is 540 km from the east to the west. It is bordering Sweden, Norway, Russia and the Baltic Sea. Finland has a population of 5.3 million inhabitants, whereas about 1 million live in the metropolitan area of Helsinki.

The Finnish Road Network

In the beginning of 2005, there were 78'168 km of public roads in Finland. 13 268 km of them were class I and class II main roads, including 653 km motorways and 146 km semi-motorways. However, public roads constitute only about 17 % of the length of the road network. In 2003 there were about 350 000 km of private roads and about 26 000 km of streets.

The motorways are mainly located in the south part of Finland and connecting its capital Helsinki with the other large Finnish cities Turku in the west, Tampere in the north-west, Lahti in the north-east and the eastern corridor to the Finnish-Russian border. Not all of these sections are yet complete. Some small parts of motorways were built around the larger cities in Middle- and Northern-Finland (e.g. Jyväskylä, Kuopio, Oulu and Tornio).

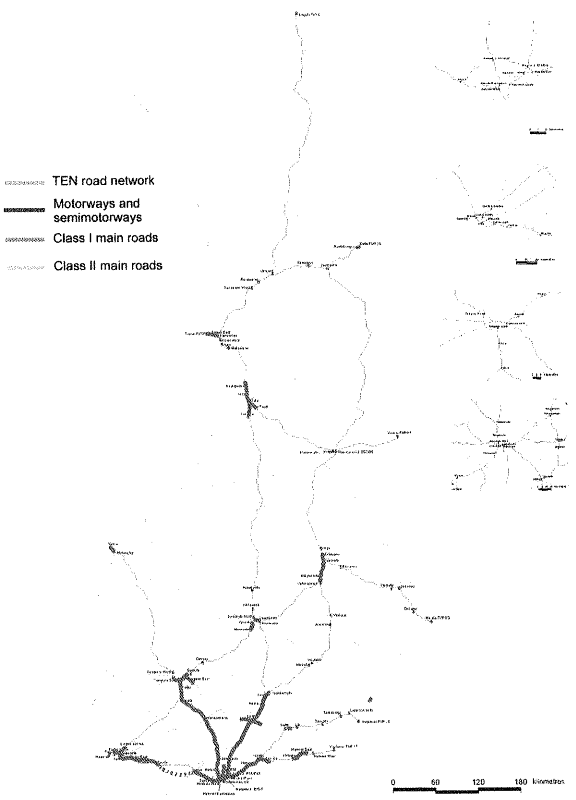

Figure 1. TEN road network, motorways and semi-motorways and class I and class II main roads.

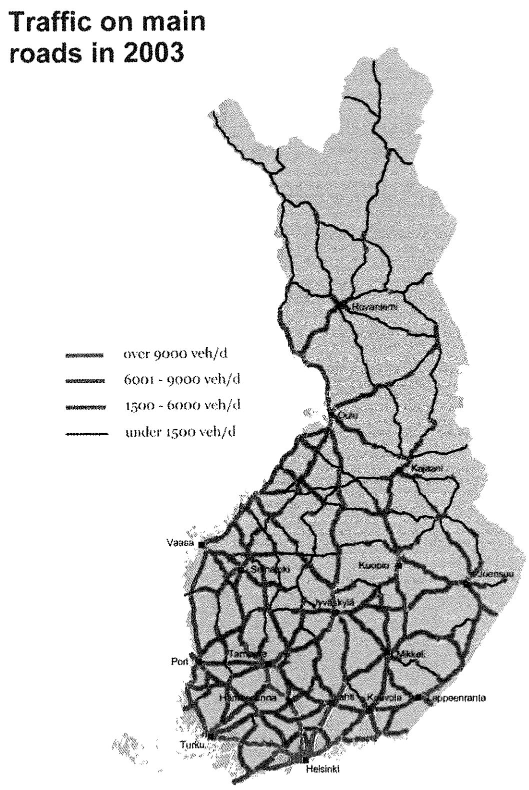

Figure 2. Traffic on main roads in 2003.

About 2/3 of the whole mileage is produced on public roads and about 63 % of it on class I and class II main roads. Most of the Finnish public road network (64 900 km) consists of regional and connecting roads. They represent only about one third of the mileage. As shown in Figure 2, most traffic takes place in southern Finland on the motorways around Helsinki and on the southern east-west corridor.

Taxation of road traffic

The taxation of Finnish road traffic is fiscal, i.e. funds are collected for general use within the state budget. In Finland, the importance of these taxes for the state economy is bigger than on average in Europe. The collection of taxes is not related to the costs of road keeping or social costs of transport. Road taxation has very few elements that could impact traffic, if not the number of different taxes and their rates are considered as such elements. Some road traffic taxes have occasionally been characterised as environmental or energy taxes although the taxation basis does not support this view.

Road traffic taxation consists of automobile tax, vehicle tax (basic tax and propulsion tax), and fuel tax. The quite high automobile tax is levied as a car is registered in Finland. The quite reasonable vehicle tax is levied annually for cars and vans in the vehicle register, and the fuel tax is included in the retail price of fuel.

The automobile tax was introduced in the late 1950's and it is based on the tax value of the vehicle. The tax rate has been lowered due to taxation harmonisation pressures from the EU. The basic vehicle tax was introduced in the 1990's on fiscal grounds. There are two rates based on the age of the vehicle. Older vehicles have a lower tax. The basic vehicle tax is calculated per calendar day. The propulsion tax is levied on diesel vehicles (plus electric and gas driven vehicles) based on the weight (own mass) and it is also calculated per calendar day.

The history of the fuel excise tax is fiscal except for the supply precaution fee. The tax includes an environmental surtax that depends on the carbon content of the fuel.

For 2006, in total a tax income of 4060 M€ was budgeted in the state budget.

Road financing framework in Finland

In Finland, road keeping is financed from the state budget. The Parliament grants funds for road maintenance and construction within a budgetary frame. Some new motorway investments have lately been financed with separate financing (BOT) outside the frame.

The state expenditures for public roads were in 2003 in total 775 M€. The share of basic road keeping was 627 M€ and the share of construction investments 148 M€ (incl. projects with separate financing).

The financing of the road network differs from the financing of railroads, waterways and airports, for which fees are charged according to their use. Regarding the rail network and waterways, the revenue is directed via the state budget back to maintenance and construction of the infrastructure. The Civil Aviation Administration is organised as an independent public enterprise financed by funds generated by the operations.

Legal Principles

When talking about road user charges, some basic legal principles have to be respected. In principle, taxes and fees are a matter of subsidiarity and every Member

State of the European Union is free in designing its taxation system. However, road user charges go beyond mere taxation since road charging systems have an impact on neighbouring countries. Hence, some aspects of road user charge systems are touched by international regulations.

UN Conventions

United Nations Conventions touch very fundamental matters and reach beyond European law. The "Vienna Convention" (UN Convention on Road Traffic from 8 Nov. 1968) stipulates basic rules for international road traffic. In Chapter III the Convention defines under which conditions one country has to accept vehicles coming in from other countries. According to the Convention, each signatory state has to unconditionally admit vehicles to their territories if they fulfil the requirements of the convention. No state is allowed to have new specific requirements on vehicles as a condition of entry. Since electronic fee collection devices are not mentioned in the Convention as mandatory equipment for vehicles, every state has to allow foreign vehicles on its roads, whether they are equipped with an on-board unit for fee collection or not. This means that it is not possible to require foreign vehicles to have a suitable on-board unit installed and you have to offer an alternative charging solution.

Two things are noteworthy in this respect:

- The UN Convention explicitly allows that different rules apply for national vehicles.[1]
- The UN Convention only applies to equipment that can be considered being part of the vehicle. It does not apply to equipment carried with the vehicle. Hence, the UN Convention allows that vehicles are only accepted on the road network if the "carry" certain equipment without "installing" it[2].

European Legislation

Concerning European legislation, two have a major impact on RUC systems. These are the requirements of equal treatment of all users and of the absence of fiscal barriers to trade. These principles apply to all European legislation, and can be found, e.g. in the Eurovignette Directive.

Equal treatment of all users means that if two users use the same road under the same conditions they shall pay the same charge. This requirement is absolute, non-negotiable and exact to the Cent. In practice it means for RUC systems that users have to be treated equally irrespective of which technical solution they use. Frequent users will most likely use some form of electronic on-board equipment, whereas occasional users will be offered a less sophisticated option for payment, e.g. a paper ticket. Irrespective of whether a user is equipped with an OBE or uses a manual system access it must be ensured, that he always pays exactly the same. It is not

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[1] For example, in France there was until recently a traffic regulation that required all vehicles to have yellow headlights. An example regarding charging is Switzerland. All Swiss vehicles above 3.5 tonnes are liable to the heavy vehicle fee LSVA and must be equipped with an OBU.

[2] This means that you can make a fee collection OBU mandatory if there is no need to install it. Austria has decided to do so. All heavy vehicles that use the Austrian motorways must carry a small OBU (called "Go-Box"). This box is simply sticked to the windscreen of the vehicle and can easily be removed anytime.

possible, e.g. to charge equipped users with a correct kilometre-dependent tariff and to charge occasional users with a simple lump-sum day pass.

This stringent requirement means in practice that charging systems are limited in their capabilities. With a suitable high-tech OBU installed in every vehicle, nearly any conceivable charging concept could be realised. But some users will for a foreseeable future not be equipped, especially occasional users and a majority of foreign users, and for these users a more simple or even manual solution has to be offered. For reasons of equal treatment the charge must be the same whether or not a user has a unit installed, and hence the simple/manual solution determines the charge sophistication that can be achieved[3].

The “absence of fiscal barriers” is the second principle of European law with a major impact on road charging systems. European law requires that there shall be no barriers to free trade. Foreign companies shall have the same access to the markets as national ones. For RUC systems this means that it is important that the charge does not interfere with the free movement of goods and services. The most critical aspect in this respect is system access.

For a national user it is only a small effort to equip all his vehicles with electronic equipment that allows for an automatic collection of road user charges. For a foreign user installation of an OBU often is too time consuming and too expensive. For such users (foreign and occasional ones) one has to offer a “non discriminating” system access, meaning a solution where the user can use the charged network with only a minimum of time delay and a minimum of financial investment. These requirements are generally considered as fulfilled if a user can pay he charges with a delay of no more than 10 minutes from his normal route and with a financial investment of clearly less than an average trip on the charged network.

Germany has decided for an OBU based on GPS and GSM technologies. Installation of these units takes a few hours. Hence, a non-discriminating alternative has to be offered to infrequent (especially foreign) users. In Germany this has been implemented by means of self-service booking terminals where a user can buy a ticket for a certain motorway trip in advance. These terminals are non-discriminatory, i.e. not a barrier to free trade, since they are located close to the motorway entrances, are open 24 hours all days and it takes only a few minutes to buy a ticket.

Austria has decided to go for a very simple DSRC-type OBU. This OBU has to be carried by all users. The solution is considered as non-discriminatory since the OBUs can be obtained all day at service stations close to every motorway entrance within less than 10 minutes. For the OBU only a handling fee of 5€ has to be paid.

In addition, there is also a legislation concerning technical issues of a RUC system, e.g. the Directive 2004/52/EC on “the interoperability of electronic road toll systems in the community” which was adopted in April 2004. The EFC Directive covers all types of road fee on the entire Community Road Network, urban and interurban, major and minor roads, and various structures such as tunnels, bridges and ferries. The

[3] To give an example in more practical terms: with current satellite location technology as a basis, very flexible and sophisticated charges could be implemented, but the manual booking terminals that are required for the non-equipped users can only issue tickets that do not allow for differentiation according to time of day or do not allow to charge a complex road network.

objective of the Directive is to create a "European Electronic Toll Service" (EETS) where every user can use all charged networks with a single piece of equipment and with a single contract. In order to achieve this goal, the technologies used for charging have to be harmonised. Therefore, new electronic toll systems shall, for carrying out electronic toll transactions, use one or more of the following technologies:

- satellite positioning;
- mobile communications using the GSM GPRS standard;
- 5,8 GHz microwave technology

The EFC Directive does not apply to:

- Road toll systems with no electronic means of toll collection (e.g. Vignette systems);
- Electronic road toll systems which do not require the installation of on-board equipment (e.g. systems based on automatic licence plate reading)
- small, strictly local road toll systems for which the cost of compliance would be disproportionate to the benefits (e.g. local bridge tolls)

General Principles for RUC

An important part of the pre-study report identifies relevant aspects of a full and operational RUC system, such as RUC objectives, network to be charged, vehicles to be charged, tariff structure, technical solutions, enforcement issues, handling of occasional users, privacy, data security and implementation aspects.

RUC in Europe

Another important part of the report presents most of the RUC systems in Europe. The most interesting and advanced ones, i.e. the HGV RUC systems in Switzerland, Austria and Germany are presented quite in detail. As a summary, the following map indicates the countries where some kind of RUC are currently applied (it is mainly Finland and the Baltic countries, that are not applying RUC at all).

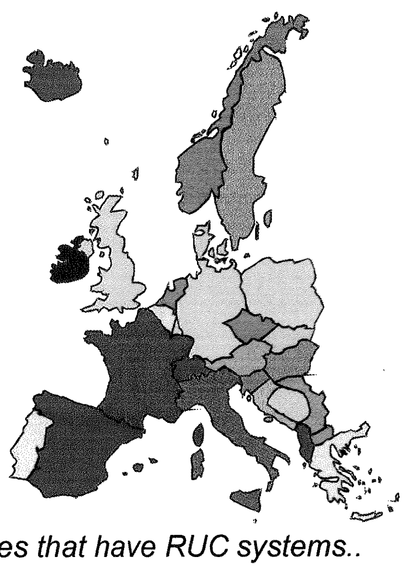

Figure 3. European countries that have RUC systems..

High Level Objectives for RUC

The working group for the pre-study considered the following high-level objectives to be quite generally acceptable:

- taxation should move from buying and owning an vehicle to the use of it
- on a general level, the level of transport taxation should not increase
- sustainability of the transport system must be part of the RUC policies
- all road users should contribute to the costs of the road infrastructure in accordance with their contribution to the usage of and damage to the infrastructure (e.g. foreign vehicles, heavy goods vehicles)
- RUC can be applied for many reasons in parallel: financing, fairness of taxation, demand management
- RUC must be accepted by the majority of users
- therefore earmarking of the revenue (in case of tax instead of fee) for improving the charged transport system is to be guaranteed (in urban regions revenues can be used to improve all transport modes)

Other aspects that have been brought to the discussion during the work are:

- in the long term, the On Board Equipment (OBE) needed for RUC is believed to be an integral part of the vehicle and support not only the EETS (European Electronic Tolling Service) but also other Traffic Management (TM) functions like emergency call (eCall), navigation, floating car data collection (FCD), Road traffic and traveller information (RTTI), etc.
- as Finnish industry is quite advanced in information technologies and especially in cellular network technologies, there is a view, that this area could be an opportunity for the Finnish industry
- it seems inevitable to formulate a RUC strategy, that allows for a staged implementation; i.e. the RUC development path can be different for private cars and for heavy goods vehicles (HGV) or concern in the early stages only parts of the network.

RUC Opportunities for Finland

For the situation in Finland, the study team created the following table which shows various taxation and road user charging principles. It compares a mere taxation of vehicles, a road user charge system based on a vignette, charging of specific parts of a network, of a cordon and the whole road network. It also takes into consideration the road network, the classification and charging of vehicles, traffic management, the financing of road operations and maintenance.

Conclusions

The study gives a good overview on the various possibilities for road user charging on the technical, legal and operational side. However, it is to be understood, that the pre-study not had the aim to make proposals but only to lay a solid base for further work. The Ministry of Transport and Communications will now set up a working group to look at Road User Charges for Heavy Goods Vehicles on the short term. Another working group will look at long term options possibly including distance based charging for all vehicles.

	0. Current taxation	1. Vignette	2 a. Yearly road user fee	2 b. Charging on road sections	2 c. Charging in zones	3. The vision: Fair and efficient pricing
Scope	All Finnish vehicles, the whole network	HGV or all vehicles, major network (TERN)	All vehicles on public network	All vehicles on charged roads	All vehicles in charged zones	All vehicles on public roads and streets and on private roads
Basis for fee	Value, class, age and use of vehicle (fuel consumption)	Connection to road keeping costs based on Directive; vehicle characteristics	Cost of road keeping (maintenance and capital); vehicle characteristics	Average capital and maintenance costs, vehicle characteristics (weight and size), mileage	Average capital and maintenance costs, size of vehicle, time of use	Cost of road keeping (maintenance and capital) + external costs (time, location, road class, vehicle char., mileage)
Charging	Included in vehicle and fuel retail price, yearly vehicle tax	Yearly payment, at point of sales and borders or in advance	Yearly payment, at point of sales and borders or in advance	Payment based on OBU or declaration before/after use	Payment based on OBU or declaration before/after use	Positioning or distance measuring
Steering effect	No steering effect	Amount of (foreign) transit traffic, vehicle characteristics	Vehicle characteristics	Time of use, route choice	Time of use and modal split	Used road sections and road class, modal choice, time of use, vehicle characteristics
Relation to road maintenance costs	No relation	Loose relation	Matches in average	Matches in average	Matches in average	Exact relation
Relation to external costs	No relation (except small connection regarding energy tax)	Loose relation	Loose relation	Loose relation	Loose relation	Exact relation
Subsidies	From private cars to goods and public transport; from south to north of Finland; from domestic to foreign transit transport	Current subsidy of foreign transit traffic ends	Subsidies according to political decisions	Funds for extension of tolled roads (more capacity)	Funds for more capacity, better public transport or light traffic conditions	Subsidies according to political decisions
Costs-by-cause principle of road keeping	>> 100 % (theoretical), mainly domestic	Foreign vehicles take part in costs	Costs-by-cause principle for capital and maintenance costs of road network	Costs-by-cause principle for capital and maintenance costs of specific road sections	Costs-by-cause principle for capital and maintenance costs within specific zones	Costs-by-cause principle for keeping public roads and street and private roads

THE DIRECTS ROAD CHARGING PROJECT – WHAT HAS THE UK DEPARTMENT FOR TRANSPORT LEARNED?

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ABSTRACT

Following on from its comprehensive Motorway Tolling Trials in 1996/7, the Department for Transport (DfT) embarked upon a further programme of research to investigate a complete pilot road charging system. This encompassed the issue and fitting of On-Board Units (OBUs) in volunteers' vehicles through to the delivery of dummy monthly invoices and dummy Penalty Charge Notices (PCNs). The one-year operational phase of the programme completed at the end of March 2006 and the key learning from this process, from the DfT's perspective can now be presented as far as the current analysis to date can allow. It is hoped that a fuller picture can be provided at the Conference as ongoing analysis work continues.

BACKGROUND

The Department for Transport (DfT) has pursued an extensive research programme on Road Charging, beginning in 1996/7 with an assessment of two separate systems considered in the context of their suitability for Motorway Tolling operations. The comprehensive report on the results recommended (in 1998) that the DfT should not consider a real implementation without undertaking a pilot trial of an end-to-end system. This led to the definition of the DIRECTS (Demonstration of Interoperable Road-user End-to-end Charging and Telematics System) Project.

In addition, there were issues surrounding the development of CEN standards for Dedicated Short Range Communications (DSRC) at 5.8 GHz in Europe. Given the potential for a large number of schemes across England and Wales, the DfT targeted the demonstration of interoperability as a key component of the emerging requirements from the project. Recognising that there could be a large number of Local Authority systems in the longer term, the Department developed a business model that would remove the need for each charging system to procure its own dedicated back office to support users. Fundamental components of the approach included:

- Targeting of one OBU per vehicle
- A single account per customer
- A single invoice per period (eg monthly)
- Competition in the supply of each organisational role in the model
- A clear investigation of over and undercharging performance end-to-end
- Demonstration of compliance with the UK Data Protection Act 1998.

The DIRECTS contract was let to the Fareway consortium in 2001. The consortium comprising KBR, Atkins and Thales supported by a number of subcontractors, has delivered:

specifications; systems; factory testing; track installation and testing; on-road installation and testing; and a one year operational period that completed in March 2006.

To measure the performance of the DIRECTS systems independently, DfT also contracted for the development of a separate Data Capture and Analysis Facility (DCAF) by SEA Ltd. This system was sent data flowing around between the DIRECTS system entities. This provided the basis for comparing against the claimed system performance from Fareway, and to support monthly operational and performance payments from DfT.

Now that the programme is effectively complete, what has the DfT learned from this extensive programme?

The complexity of the project has illustrated that even relatively established technologies offer practical integration and operational challenges in delivering a representative operational system. The ability of such systems to generate large volumes of data makes heavy demands on the ability of tools and specialists to draw information from this.

The output and learning can be categorised under four headings as follows:

- Specification preparation
- Practical proof of concept for the DfT road charging business model
- End to end performance evaluation
- Demonstration of interoperability.

Each of these will be discussed in more detail in the following sections.

SPECIFICATION PREPARATION

The DfT spent some considerable time and effort to create the technical and commercial requirements for DIRECTS. Explicit deliverability of each of these was sought as part of each tenderer's proposal. This early investment paid off in the operation of the contract as far as DfT was concerned. However, the ability for all technical requirements to be met was not achieved in operational practice and compromises had to be made to keep the programme 'on-track' during its execution.

One of the key outputs from the DIRECTS programme has been the creation of the Open Preliminary Minimum Interoperability Specification Suite (OPMISS), setting requirements for road charging systems and services. This is a three volume set of documents addressing:

- Systems description, functional breakdown, and technical and performance requirements definition for all relevant entities in the DfT business model (see next section)
- Definition of interfaces between these entities
- Definition of the DSRC interface between off-board, account based On-Board Units (OBUs) and Roadside Equipment (RSE) together with associated conformance testing materials (Refs [1] and [2]).

This material is in the process of being delivered in draft to DfT, undergoing specialist review, and will subsequently be formally issued by the Fareway Team for DfT to develop further.

DfT will use this material as a key input to its wider Road User Charging programme, focusing on the introduction of Local Congestion Charging schemes as part of the Transport Innovation Fund (TIF) programme.

PRACTICAL PROOF OF CONCEPT FOR THE BUSINESS MODEL

The implementation of the DIRECTS project effectively demonstrated two separate charging systems (for example representing two different towns) with two further organisations supporting user account, billing, and enforcement processes. The project demonstrated that much of the costs of operating systems such as these lie in the 'back office' and that these can vary according to the strategies employed (for example in regard to the degree of human review of enforcement images). The model is illustrated in Figure 1 and has remained substantially unaltered in the course of the DIRECTS project.

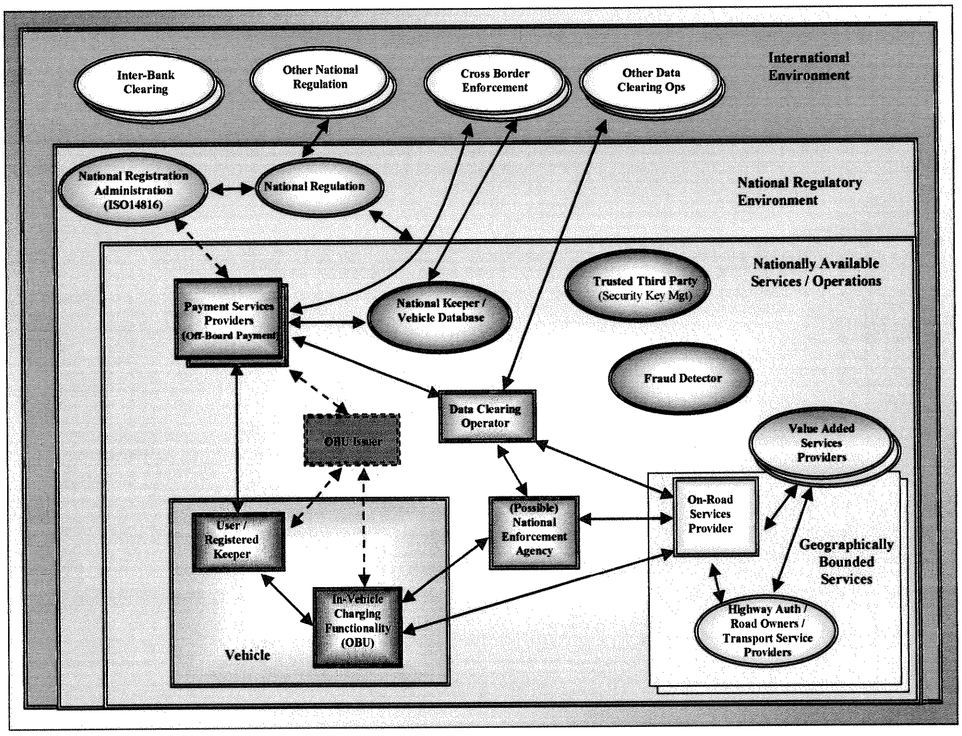

Figure 1 –Road Charging Business Model covered in OPMISS Specifications

Overall, the demonstration work confirmed that in technical and operational terms the model is fit for purpose and could form the basis for live operations. However, this is only part of the story since the contractual and commercial framework within which such a business model would operate has not yet been defined. Consequently, until there is progress in these two domains, it is not clear that the model represents an approach where all entities can be sourced in a competitive environment. Whether this is contracted by government, develops naturally, or a market is catalysed in some manner where businesses could make a viable return remains to be determined.

Parallel work as part of the European Commission's CESARE III Project is looking into the contractual baseline for operations between some of the entities identified in the model. However, it is still not clear whether draft contracts that would support private toll operations and national / local government owned schemes could be created, and enable seamless operations in the longer term (mainly in the context of the planned European Electronic Toll Service (Ref [3])).

Work has recently been undertaken within DfT to consider the suitability of ISO 24014 (Interoperable Fare Management) as an alternative business representation that could strengthen the case for industry involvement in supplying competitively sourced, cost effective services to road charging schemes. The intent would be to deliver interoperability as a major outcome, as has been achieved in the UK for its Integrated Transport Smartcard Organisation (ITSO) that was co-sponsored by DfT. This work is ongoing and may result in some re-casting of the DIRECTS model and the OPMISS materials.

PERFORMANCE EVALUATION

Transaction Performance

As outlined previously, the DfT set requirements upon the demonstration in terms of targets for over and undercharging. These measurements were undertaken in the context of an overall need to capture a minimum of 600,000 Dedicated Short Range Communications (DSRC) transactions at 5.8GHz. This was supported by corresponding measurements from an independent Automatic Vehicle Identification (AVI) system installed on roadside structures and separate AVI devices within each equipped vehicle. As a further complication it was agreed that payments for DSRC transactions would be based upon matched DSRC and AVI transactions, which relied to a great degree on the AVI performance which was lower than the DSRC performance. In addition there were a small number of GPS / GSM based OBU referred to as MPS (Mobile Positioning System) devices that used GPS to detect charges against and on-board map of 'virtual gantries', zones, motorway links and a charging grid based on 'cells' of either 250m or 500m square sides. The grids were set in East Leeds and Southwark in London (as part of Transport for London's (TfL's) own technology trials). The actual number of successful DSRC, AVI and MPS transactions recorded over the course of the 12 month trial are presented in Table 1 below.

Month	Apr 05	May 05	Jun 05	Jul 05	Aug 05	Sep 05	Oct 05	Nov 05	Dec 05	Jan 06	Feb 06	Mar 06	Totals
DSRC Transactions	60264	66961	80921	73526	76937	75660	68277	67302	59980	62490	53883	59788	805989
AVI Transactions	52053	53686	55613	61780	61531	60325	51584	49834	53343	55072	50999	57350	663170
Matched Transactions	47205	47467	52311	48165	53323	54757	45413	43895	43409	44833	45825	50577	577180
MPS Transactions	9919	7566	10255	9666	9216	7498	5933	7392	14339	27890	26191	30550	166415

Table 1: Number of DIRECTS Transactions (Data Capture Phase)

During this period, a number of faults affected the performance of the Roadside Equipment (RSE) in terms of capturing DSRC transactions. Figure 2, summarises the underlying performance when periods of known RSE faults are excluded from the analysis.

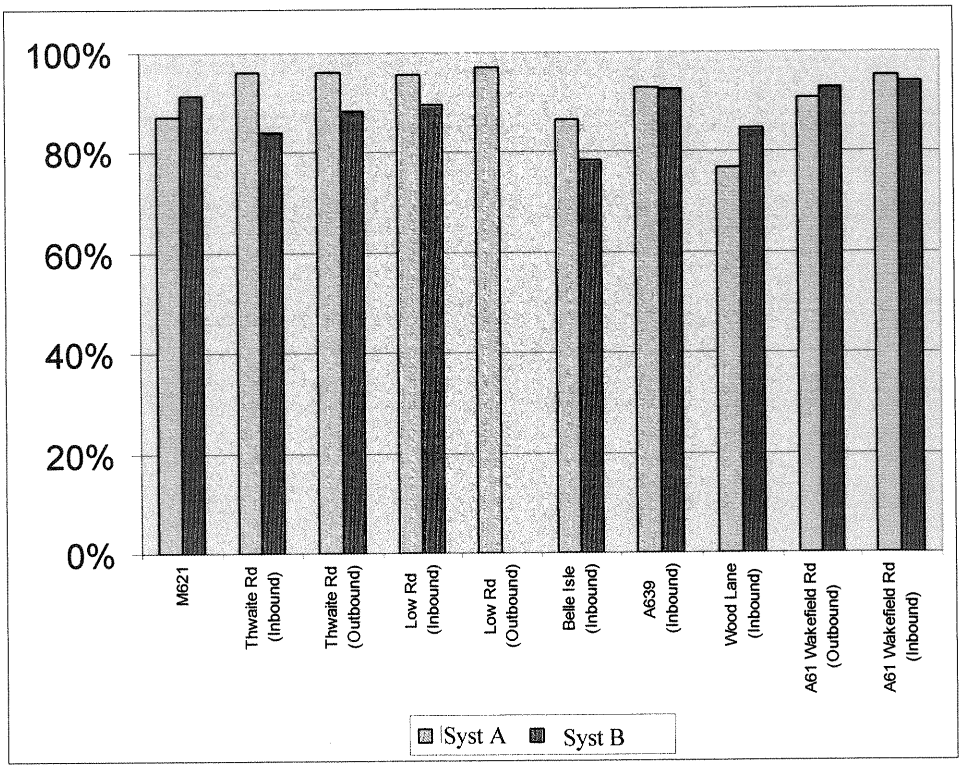

Figure 2 – Underlying DSRC Performance By Site

With exclusions allowed for, the average combined actual performance across the 7 sites was 91.1% (sample: out of expected 645,485 vehicle passages). The average underlying performance across the sites was 92.8% for system A (sample: out of expected 328,783 vehicle passages) and 89.4% for system B (sample: out of expected 316,702 vehicle passages). However, it should be understood that there were many factors that contributed to this lower than expected performance, particularly the actions of users and the impact of OBUs falling from screens etc. Limited testing using a set of specific test vehicles with correctly configured and mounted OBUs generally delivered much better overall performance. It is also worth noting that as there were no real costs or penalties involved, volunteers were not incentivised to ensure their OBU was operational at all times.

Consequently, the conclusions drawn from this output is that the systems as designed and configured would contribute performance that would be insufficient in an operational free flow environment. Subsequent investigation into Urban Charge Point specification as a joint exercise with TfL, supported by their more recent technology trials, has been promising. Performance has been higher than illustrated above, but again in the context of properly configured and maintained test vehicles. This work has shown that careful charge point design, encompassing the provision of low visual intrusion structures with careful attention to road coverage footprints for image capture systems and DSRC beacons, can provide the conditions for better performance. In addition, it should be noted that the DIRECTS systems were 2001 designs and one of these was a prototype conceptual approach, which was not known to Fareway or the DfT at the time the contract was let. This 'solution' is not marketed as a product today.

Image capture performance - real time video analysis

From time to time, one of the DIRECTS equipped sites would be put into a mode where unequipped vehicles had their image captured and equipped vehicles (of which there were only a very limited number as a proportion of the total traffic) were 'ignored' as far as the image capture system was concerned. The periods of such operations were generally long enough to allow around 2000 vehicle passages during each specific test. There were no links to the UK vehicle database so all the images collected were analysed for the purpose of creating dummy PCNs. An analysis of separate Real Time Video (RTV) data, compared with the DIRECTS image capture system is presented in Table 2 for samples of these test periods.

Table 2 - Summary of Real Time Video results

Overall Counts				
RTV Analysis	DIRECTS Image Capture System	DSRC Equipped Vehicles† Passing Test Sites	Missed Vehicles*	Performance*
16362	14663	368	1331	91.7%

* Does not allow for Real Time Video or Fareway miscounts, or for unreadable Vehicle Registration Numbers.

† Includes all DSRC vehicles irrespective of whether an image was taken.

Overall, the performance of the image capture system proved to be an issue during the majority of the testing and operational phases, with equipment triggering and reliability problems. As indicated above, the more recent TfL trials have given much greater confidence that high performance image capture can now be expected in an urban environment at modest speeds.

Over and undercharging

The over and undercharging targets were based around requirements for the accuracy of fixed line telecommunications billing (updated reference at Annex A of Ref [4]) and for the target of 600,000 DSRC transactions the aim was for Fareway's end-to-end billing process to incur no more than 6 (ie 0.001%) overcharged events and no more than 36 (ie 0.006%) undercharged events at a 95% confidence level. Achieving these targets would enable Fareway to obtain the highest potential performance payments at the end of the operational phase. In practice, the two targets were separate and Fareway took a decision to concentrate on meeting the overcharging target at the expense of the undercharging target.

From a lessons learned point of view, DfT should have linked to two separate targets in terms of minimising both over and undercharging events in the course of the trial. The consequence was that Fareway concentrated on meeting the overcharging target which led to operational strategies that resulted in many thousands of undercharging events in the course of the one-year programme (with no contractual penalty). The headline overcharge count determined by Fareway was close to a target of 9 (95% confidence level for over 800,000 DSRC transactions actually captured during the trial). However the DfT perspective, informed by the independent DCAF analysis, suggested that there were other instances of overcharging that were a source of 'discussion' between DfT and Fareway before agreement on the value of the bonus payment for this programme element.

So in summary, DfT set split targets and achieved unintended outcomes that provide a lesson for the definition of Service Level Agreements for future systems. In addition, the performance of the front end systems leads to a view that using telecommunications billing targets are unlikely to be achievable, and that the level of performance expectation was unrealistic. In practise, it is likely that an operator would always try and minimise overcharging as it causes increased back office costs and bad publicity, and then seek to manage their loss of revenue from undercharging.

Further analysis of the results from DIRECTS are provided at Ref [5].

DEMONSTRATION OF INTEROPERABILITY

The inclusion of four separate DSRC manufacturers, who would normally be competitors, within the Fareway supply contract achieved the desired objective of demonstrating that interoperability between differing combinations of RSE and OBU designs was possible. Two distinct RSE manufacturers were involved from the outset (although now formally within the ownership of Kapsch) with a total of 6 separate OBU designs, including the demonstration of off-board and on-board accounts (provided by Kapsch (Austria), Combitech (Sweden), Thales (France) and CS Route (France)).

Even though the specifications for the implementation in DIRECTS were jointly defined and agreed by Fareway and its subcontractors, there were some slight differences of interpretation and implementation of this material in terms of the RSE-based transaction design and the functionality within the OBUs. The lesson learned here is that although authors may believe that specifications have been unambiguously written, there is always the potential for divergence either due to language interpretation or 'force fitting' the requirements to 'meet' existing product formats etc (there was no intention that new OBU designs be created for DIRECTS). Overall, the equipment demonstrated interoperable working between all OBU designs and the two types of RSE. However, in terms of implementation there were slight differences (for example some OBUs retained an electronic receipt whereas others did not require this).

The 'belief' that OBUs and RSEs were essentially off-the-shelf items requiring straightforward integration certainly proved to be a myth. The truth was that Fareway had to spend considerable time and resources to ensure that all components worked seamlessly to deliver a truly interoperable solution.

In addition, although GPS / GSM based OBUs are by their nature different in operation from DSRC devices, the outcome from DIRECTS was to demonstrate that interoperation with the same back office components designed for microwave operations was not only practicable but delivered some strong performance results.

SUMMARY LESSONS LEARNED

Although the life of the DIRECTS programme was longer than intended, the outcome has been a considerable body of learning about how a practical charging system might operate in the context of the competitive supply of different roles in a multi-scheme context. In the limited space available here, it has only been possible to present some of these.

Particular points to note are:

- Ensure that the tender requirements are carefully defined to meet the operational need – this is essential to reduce the potential for scope creep by either party and for effective change control
- Create / adopt a viable business model in contractual, commercial, operational and technical terms to be sure that implementation success is as low risk as possible and will deliver interoperability
- Consider specifying the minimum performance capability of transaction and image capture systems as part of the procurement process, particularly as operational schemes will generally not give practical performance information. These need to reflect the effects of real vehicles, real traffic and real drivers in a free flow environment
- Set realistic, linked over and undercharging targets to reflect a balance between technical and operational achievability and the expectations of the public. This requires some understanding of what is technically achievable
- Be clear about the magnitude of the integration task and be clear who is responsible for ensuring that various subsystem components can be made to operate seamlessly
- Note that independent, external vehicle classification systems have the potential to create additional exception events when comparing their output with data declared from an OBU. This may have to be processed by a human operator at some point in the end-to-end process to be properly resolved.
- Require robust planning and control processes to help prevent delays
- Introduce some form of 'partnering' agreement between all the parties to ensure that all work together for the good of the project with open communications and dialogue throughout.

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[1] Open Minimum Interoperability Specification Suite (OMISS) Volume 3 – Requirements For OBU To RSE Transactions Using 5.8GHz DSRC which is accessible from the following link: http://www.dft.gov.uk/stellent/groups/dft_control/documents/contentservertemplate/dft_index.hcst?n=14687&l=2

[2] Open Minimum Interoperability Specification Suite (OMISS) - Test Specification for Volume 3 - Evaluation of Conformity of OBU and RSE to the Transaction Requirements using 5.8 GHz DSRC which is accessible from the following link: http://www.dft.gov.uk/stellent/groups/dft_control/documents/contentservertemplate/dft_index.hcst?n=14687&l=2

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REPLACING THE FIXED-FEE EUROVIGNET WITH A MOBILE SYSTEM TO COLLECT VARIABLE-FEE ROAD CHARGE FOR HEAVY LORRIES

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ABSTRACT
This paper discusses a telecommunications-centered solution for charging road use for lorries. The implementation option for collecting fees on highway roads is based on an innovative method. Instead of physical toll collection with enforcement stations on many segments, a 'virtual toll collection booth' is possible. The mobile network can be used to identify traveled distances.

Backgrounds of the Dutch situation are provided. What roads will be charged? Which interaction is needed? We review the business model with the process of installing units, the way of collecting data, rating, billing and payment. Specific attention is given to the context of interoperability.

KEYWORDS
Toll collection, SIM-card, GSM, UMTS, GPRS, GNSS, Eurovignet, Lorries, Interoperability, electronic toll collection (ETC), electronic fee collection (EFC).

BACKGROUND

Replacement of the Eurovignet

In The Netherlands, heavy traffic (i.e. lorries with a weight of 12.000 kg or more) pay a special tax for using the main motorways. This tax is called the Eurovignet. The tax is levied for a whole year, irrespective of actual use. The intent is to replace this fixed tax with one based on a road segment based scheme. In replacing the fixed fee tax with a variable tax, the Ministry hopes to find a way to reduce the heavy traffic mileage: the increase of transport is projected to be 40% - 80% until 2020 if no measures are taken. Additionally, the variable charges can be used to pay specifically for road maintenance based on actual use of a particular road segment.

Requirements

Pay for actual use with the distance traveled on the motorway system is based on the accumulation of segment lengths of the traveled road. The motorway system in The Netherlands is made up of 1.150 segments (between access ramp and exit). The price is based on actual weight during a specific trip (as determined by the number of axles in use) and administered to all (inter)national freight trucks above 12.000 kg. Enforcement should be simple and effective. Interoperability is needed: the drivers with a unit from another country should have access to the road-pricing administration without needing a special unit. Visibility of the price paid (insight into the charges) in the truck cabin. Privacy is no issue for commercial traffic. The infrastructure should be shared with that for charging distance to private cars. The cost of ownership should be low. An average charge record is about € 0,12 - 0,15. One should relate errors to this fact.

The existing alternatives

Several countries have solutions for electronic fee collection. The most known is the German Maut system based on GPS positioning and a charging unit in the vehicle, with transfer of bill data via GSM. In Austria a DSRC-based identification of vehicles and retrieval of vehicle classification is used. In Switzerland a mixed system of DSRC/GPS is used. Gantries are used for detection or data communication and they also form an infrastructure for enforcement.

In all these options a unit in the vehicle allows electronic tracking for enforcement. The Austrian and Swiss models allow checking payment just on this electronic identification; the German system needs a special 'probing' in the on-board unit to verify actual payments.

The Dutch situation shows the highways are tightly intermeshed, with 1.100 sections on 1.500 km of highway. This would imply 1.100 gantries. The economics are not favorable, with a price per gantry between € 150.000 and € 300.000 depending on the number of lanes and the equipment installed: we *guestimate* an infrastructure budget for a DSRC based system of € 200 million, and of the GPS/GSM based concept some 40% higher.

A new alternative

We propose a variant that is slightly different from the existing schemes but the change has big advantages. We propose to reduce the intelligence in the vehicle and store actual use directly in a central administration.

An on-board unit will have a mobile identity and the presence in a specific cell is detected. By having a good mapping of cells to roads, the presence on a specific section can be detected. By having several cells sequentially, and taking allowance of the radio coverage the section that a truck is driving on can be identified unambiguously.

The design aim is to create a 'thin OBU' (on-board unit) that just facilitates detection but does not translate the presence into positions and road segments on a digital map. A server in the central administration does this work of detection the actual segment and deriving the length and cost.

- The idea of using cells is not new at all. In fact, the Genion product that was launched by O2 Germany in 1999 is a cell-based offer for a home-zone pricing option. The concept offered users at least a 60% discount when using their mobile within their home zone – in fact a direct attack on the use of the fixed line at home. Implementations of the concept by other operators were for example a 'shopping zone', offering users a discount when calling from a shopping centre. KPN Mobile offered a discount for 'local calls'. The author proposed a similar product concept for a GSM service provider that was related to a travel agency in 1995: give customers who buy a holiday, a discount on GSM-use along the route: "*A sunny price on the Route du Soleil*" (the name of the main highway in France for heading towards the popular holiday resorts). GSM billing systems like BSCS support cell-based rating.
- Several commercial location-based services are able today to track vehicles even without GPS logging. Operators provide such services, based on triangulation, either on the server side or with some support from embedded software in the 'phone'.

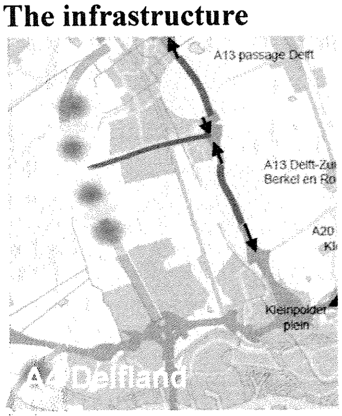
Using GPRS for infrastructure, the budget for collection and enforcement can be in the order of magnitude of € 50 - 80 million, including extra antennas and specific radio-planning. The On-board unit is still rather expensive, being a telematics unit that must allow setting parameters like number of axles (which is a parameter for the price plan).

OVERVIEW OF THE ALTERNATIVE SOLUTION

External detection of the On Board Unit

The lorry has a unit with a SIM-card that has a unique MSISDN and equipment number that also can be used for uniquely identifying the vehicle. The unit consists of an electronic ID, some user interface, an optional GNSS capture and data communications but no processing. It has an antenna used for the UMTS communications and for optional GNSS capture. The vehicle ownership and the paying party are administrated corresponding to the unique ID on the SIM card.

The infrastructure



Every segment in the highway can be defined in the UMTS radio-plan and mapped on several mobile radio cells. The context is thus defined by passing through a specific string of cells. For some sites micro-cells or fixed directional antennas might be needed.

Registering usage

In use, the unit logs in on the UMTS network. Once these loggings have been made, the road-segment that has been travelled on is unequivocally identified. The handling by the driver is reduced to almost nothing – just enter the class of use (for instance, based on the number of axles in use) into the device through a user interface. This information is transferred to the network and becomes part of the logging. Instead of a derived distance (such as from a digital map), the presence is mapped on a database with actual segments. The presence on a segment is deduced from (strings of) loggings. In the example above, presence on the highway from Delft to Schiedam can unambiguously be mapped with only a few cells. It can be used to detect use of geo-objects like roads and tunnels where a success rate of at least 99% should be possible. False recognition of such a geo-object should be less than 1 in 10^5. A filed experiment has to provide a proof. In fact, we are talking about standard schemes in use for many kinds of telematics services. The central administration keeps track of exact usage per segment and revenues can be used for specific tear and wear of segments.

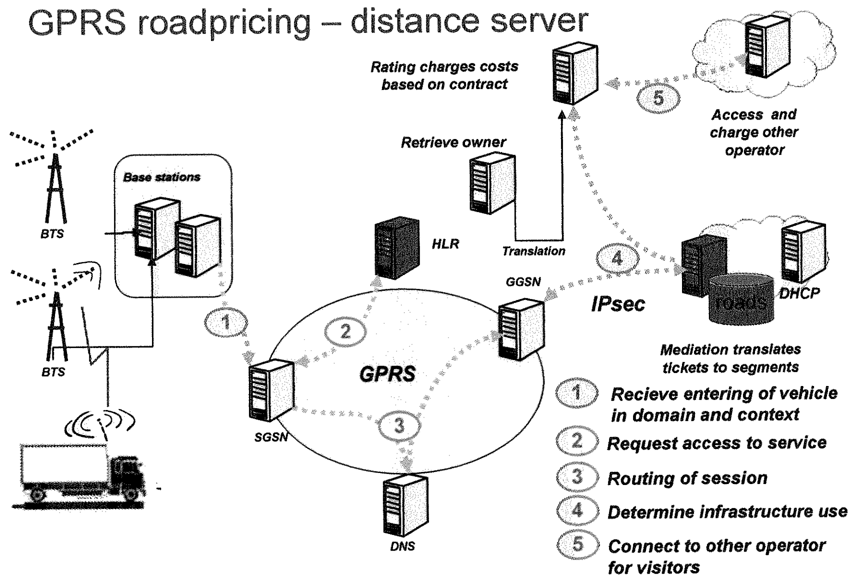
Incidental use
The system can be supplemented by a pre-booking facility where drivers can enter the data and pay for use in advance. The license plate is entered, the vehicle class (like the number of axles) plus the route that will be taken after which the cost is calculated and paid. This could be an on-line application. Most trucks have a back-office that can enter the data on a WEB-site; as well a mobile portal can be made to facilitate registering for those who do not have the native Dutch on-board unit.

Billing
The determined segments are used to derive their distances and their fixed prices. Charging is thus really straightforward. Each user pays the same amount. The owner gets a bill at the billing address, with all bill lines detailed if needed, showing all traveled moments, and so the owner can verify the bill. Note that this is a standard feature in commercial traffic; privacy is not required here by law. However, of course an owner could opt for privacy. But that is an administrative service. The use could also be deducted from a prepaid balance. All these facilities of a central administration can be shared with an administration and billing environment for private cars. The charging resembles standard telecom rating. No rocket science here. By the way, no operator would ever think about charging calls *in* the handset... and that is even quite simple compared to charging road use in an OBU (in fact it was tried; but not found reliable and very susceptible to fraud).

TECHNOLOGY

UMTS and GPRS as a network for toll-collection
GPRS allows the service subscriber to send and receive data in an end-to-end Point-To-Point packet transfer mode, without utilizing network resources in circuit switched mode. Each packet is independent of the preceding and succeeding packet. This service is of the datagram type (like the Internet Protocol). If every charge record of the OBU is not stored (semi) permanently in the unit but transferred to the central administration, then the loss of data should be taken into account. In IP landscapes, lossiness is assumed and an end-application controls the integrity and might request a resend.
The UMTS network exists and has a specific high density (bandwidth focused) on the highways. Ideally, no extra infrastructure would be needed, but current design and equipment configuration are not optimized for this purpose. This means that specific re-planning and reconfiguration is needed. Specific small aperture and low signal strength antennas can be added: low power gives small cell size and thus increased accuracy for this purpose. Additionally, special cables can be used that provide a longitudinal constant field along some hundred meters of road (the method is used in tunnels and elevator shafts for CDMA).

The active vehicle equipment sets up a session when entering a cell. In the network, the session is routed by a Service Gateway and the GPRS Gateway to a specific mediation server for calculating road-use charges. A specific UMTS Domain can be used (to provide restricted entry) and identities of visitors can be retrieved from other operators directly. Rating is based on price plans. The rating and billing servers have access to the other operators for invoicing. Not shown are administrations and registrations for customers, vehicles and license-plates, incidental bookings or enforcement.



Privacy is integrated into UMTS and GPRS

- The GPRS signaling and air-link are encrypted. UMTS has techniques for MS authentication, access control, user identity confidentiality and user information confidentiality in place to prevent misuse of access by unauthorized persons using manipulated MSs (mobile subscribers) and eavesdropping on the information exchanged on the radio path.
- A special GPRS access class specifically intended for toll payment was part of the 3GP standards from the start. It allows anonymous toll gathering while using a prepaid server. The purpose was to provide an end-to-end process that would be completely compliant to the most stringent privacy laws. In fact it was a copy of the prepaid calling concept for toll payment. When a vehicle passed into a cell it would be registered and a charge record (CRD) made. The cost is then deducted from a prepaid account. Only enforcement is allowed to look inside (with a 'PKI challenge').
- Anonymous GPRS access allows service provisioning to a mobile subscriber whose identity is unknown in the network and session management can handle anonymous session-context activation and deactivation.
- Dedicated signaling procedures can be made.
- An AAA authentication service can be added for toll-service access.
- To find the user, Advanced Addressing and Label Translation can be used. The GPRS standard identifies specifically user-labeling by means of a car registration number through a special address book service.
- S-CDRs (charging records) are generated by the GPRS Gateways in the case of Anonymous Access, where the Anonymous Access Indicator is set to true and confirms that the Served IMSI is not supplied.

An evaluation of the radio network technology

We encountered several drawbacks in the concept when discussing a field trial.

1. When GSM started it had fixed cell sizes. Dynamic cell sizing has been introduced from around 2000 as a method for providing adaptive capacity and in the mean time to save transmission power at the base stations. When the equipment is installed out of the box, the cell sizing is uniform. With radio planning tools, the effective coverage can be improved, with automatic apertures. The operator needs less frequency slots and hence antennas and base stations. The optimal design for voice calling is not the same as the best way of covering a set of roads. Another radio planning is needed.
2. Cells are often still too large and cover for instance an intersection.
3. Users are not attached to a specific base-station. They are part of a cloud.

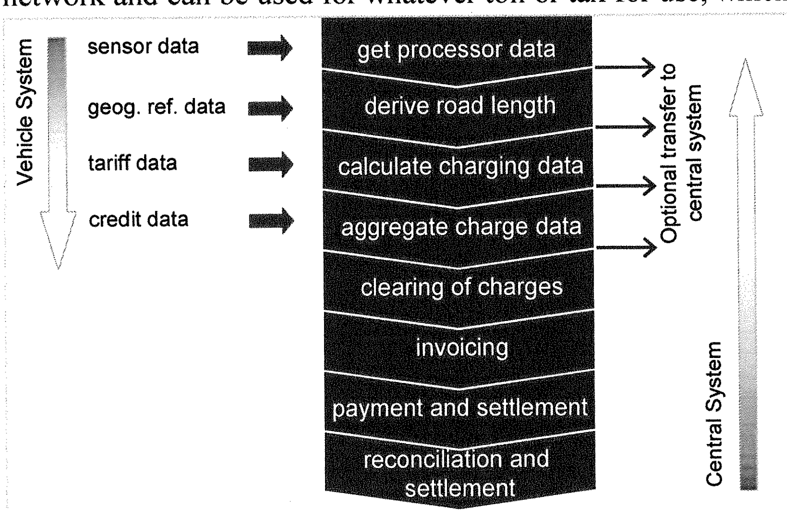
So should we give up?

1) The savings in infrastructure would compensate more than enough for some de-optimizing of current settings; as well in several countries, spare frequency is available for immediate use (Germany, the Netherlands) and thus a dedicated net could be made with non-adapting antennas.
2) At the places where an ambiguous road would exist, the unit could be requested to send a GNSS way-point as well. A cell-broadcast can be used to request such extra data.
3) This would mean going back to the drawing board and review the telematics underneath, or revert to a GNSS scheme all together (that would have a costlier data communications budget).

Use of GNSS is not compulsory in the interoperability guideline. However, when several operators use it, it becomes sort of part of a common solution. We suggest that GNSS remains an optional element of the architecture.

INTEROPERABILITY

The European Commission promotes interoperability. The basic principle is: one single contract with one single onboard unit per vehicle that can be used on the the whole European tolled network and can be used for whatever toll or tax for use, which implies a common interface. This helps to overcome a future where cabins are stuffed with many units, leaving drivers prone to costly mistakes and distracting them from attention to the road; while the economic argument is that extra facilities are a deterrent to free trade of services (transport services). A directive has been made to promote alignment. Standardization programs have been set up ; however these are not yet really binding. The ISO 17575 interface describes a common format [1]. We recommend to include ETSI in the development process. The MISTER project [2] studied interoperability and suggest compliance capabilities on several



Based on: *European standardisation and EFC, 28th June 2005: MISTER,* (by Ian Catling) levels. Our design goal is to capture only the raw data from driving (GNSS waypoints) when ambiguity is known, and further to use network logging information as much as possible. The advantage is less data transfer costs but even less reliance of easily faulted GNSS equipment.

EU interoperability guidelines states that a new toll and road-pricing systems must make use of either: GNSS (Galileo), GSM (UMTS), DSRC. We restrict ourselves to the middle option and subsequently we identify an option for enhancement with GNSS waypoints that can be handled in the central application. Of course, DSRC can easily be added on a platform for interoperability such as by the implementation of a DSRC interface in the OBU that complies with the CEN TC278 Standards and CESARE 2 / CARD-ME Specifications [3]. But DSRC might disappear from the technical roadmap.

It is our opinion that if the interoperability takes place at a higher layer, that then the specific charging algorithms have to be loaded into the on-board unit when the vehicle enters a new context. This implies quite a lot of standardization and also provides an opening for fraudulent use. A simple concept would be more future-proof.

Interoperability is modeled on roaming with GSM: when a GSM phone is used in another country, the user gets the charge on the bill (or on the pre-paid balance) at home. The electronic identity is be transferred when entering a new charging context (for us: the highway). A UMTS identity is recognized as one belonging to charging for road use. Subsequently the characteristics (class) are be retrieved from the unit or home operator. This means that some specific protocol is needed (a handshake resulting in transfer of the details).

Most payment on-board units have a GSM (UMTS) communication component as part of the system architecture. The owner can register that unit along with the license plate with the Dutch operator administration. This means that electronic recognition can take place and enforcement can be done. This is a basic interoperability. A transfer of administrative details can be done automatically with the other road pricing operator. When the unit is identified, charges can be transferred to the account of the driver through a transferred account procedure.
Ideally, there should be transparency between units. A weight classification entered on the German system or the Austrian system should be transferred by the home administration to the visited operator.

ENFORCEMENT

Surveillance can be simple: the vehicle registration is captured through camera's (license plate recognition) and each registration checked against the loggings in the central administration. If a vehicle is found faulty, the unit did not register, which means that the owner is found at fault. If no pre-booking has been done, a fine will be collected. All handling and processing is done in a central administration. The central administration is intelligent, leaving the vehicle-system rather dumb. This reduces the possibility of fraud to almost zero. Because units have no data (only an identity) no billing data is lost when the vehicle unit breaks down. No incentive for a break-down. No hassle, no fraud. And very low cost of enforcement. It can run almost completely automated and it can share a common platform of recognition with that for road-pricing for private cars.

COSTS

Costs can be divided in three areas: infrastructure, units and operational costs.

- In our proposed solution, a UMTS mobile network is used. The UMTS network is in place already, and hence the investments are low. Specific adaptation of equipment and some reconfiguration of the radio planning is needed.
- The unit can be simple (UMTS plus GNSS), with a user interface for entering the actual class. The unit must be fitted. This is a rather standard cost level of such units probably comparable with Austria or Switzerland.
- Operationally the solution is rather simple in use and hence in cost. The central administration can be based on standard application components. Specifically enforcement can be straightforward. Enforcement can be implemented through standard number plate recognition. The result can be compared with the central data. If no registry exists, ... a penalty can be charged semi-automatically. A complicated method to have access to data stored in the vehicle is not needed – such a method would either imply costly infrastructure or a large control force. The application concept is based on standard telematics. Transfer of data is an extra cost, and the use of special schemes to reduce the cost should be devised.
- Note that Galileo is not really free. Galileo will charge states an annual fee if the signal is used for national charging schemes (even when individual users don't have to pay). That is part of the business model of the operating company.

CONCLUSION

Having described the alternative and having paid specific attention to the requirements, we are left with the question: It sound OK, but does it work?
First of all, the method pays off in the long run. The cost of collecting data is low, the infrastructure is cheap per mile, and last but not least, enforcement is simple because there is no room left in the concept for broken equipment.

Like any counter-intuitive alternative, the road to success is long. The dominant idea is to implement costly equipment in trucks, prone to break-down and fraud while enforcement is very complicated and time-consuming.

REFERENCES

[1] European Commission (2006). Specification of the EFC application based on satellite technologies, *Report of Expert Group 9*, Rotterdam, the Netherlands ('Application Interface Definition for Electronic Fee Collection based on Global Navigation Satellite Systems and Cellular Networks (GNSS/CN)'

[2] European standardization and EFC, 28th June 2005: MISTER (Minimum Interoperability Specification for Tolling on European Roads)

[3] http://www.ertico.com/en/subprojects/rci/objectives/ - the Road Charging Interoperability Project (RCI) focuses on the convergence of future tolling systems; DSRC and the data communication over DSRC seems to play a central role.

[4] European Directive 2004/52/EC (the 'interoperability directive')