ROAD CHARGING IN URBAN AREAS – A DEMONSTRATION PROJECT IN THE CITY OF TURIN (ITALY)

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SUMMARY

This paper describes the approach adopted and some preliminary results of the Turin demonstration site for research studies on methods and technologies for traffic management, achieved by means of telematics road charging and automatic access control systems. Key elements of the project are solutions for automatically recognising vehicle-by-vehicle road usage in the complex environment of the urban transport network. The research focuses on both technical and organisational architectures able to achieve high-precision localisation and optimal distribution of functionalities between onboard equipment and central systems, while balancing the strict and competing requirements of low costs for on-board devices and communications, high reliability of applied charging as well as flexibility and interoperability. The onboard terminal will be able to deliver value added services to the users, allowing third parties to easily develop VAS services. Demonstrated functionalities will be extended up to selective demand management based on environment criteria, such as speed and emission levels.

AIMS AND BACKGROUND

The aim of the research project being undertaken in Turin is to define the methods and technologies required for the management of the urban road infrastructure (car parks, roads, restricted areas) in terms of access control and payment.

The growing reliability of telematics devices means that it is now realistic for many of the processes involved in access control and billing to be dealt with automatically. This solution would have the advantage of allowing a flexible approach to traffic control by introducing selective demand management schemes, resulting besides in a useful way of monitoring traffic and providing information on traffic flows. It would in addition facilitate the implementation of other user services at a low cost, for instance speed warning/speed suggestion, Point Of Interest information and dynamic route planning.

Turin has been selected as the site for pilot experimentation. The intention is to extend and deploy the application subsequently in other sites in Italy, achieving a considerable reduction of costs for the system and benefit for industrial and economical development in several sectors.
URBAN ROAD NETWORK: A SCARCE, POLLUTED RESOURCE

In a recent report of the World Business Council of the Sustainable Development the following is stated:

- **Congestion appears to be increasing.** Though reliable cross-national data are hard to find, there are indications that levels of congestion are being perceived as increasingly disruptive by the general public.

- **Emissions from motor vehicles** account for much of the air pollution in urban areas and for the majority of global transportation-related greenhouse gas emissions.

- **Mobility systems need to become more efficient, more equitable, and less environmentally and socially disruptive.**

- In virtually all developed-world urban areas, the automobile plays the dominant role in providing urban mobility. Auto ownership and use has grown substantially over the last 50 years. This, in turn, has facilitated suburbanization and lower density development, damaging public transport’s competitiveness. Though public transport remains important, especially in Europe and Japan, its share of total developed-world passenger miles has been decreasing almost everywhere.

- A range of strategies is being tried to offset the adverse impacts of motor vehicles. These include traffic management strategies, promoting the increased use of public transport, the use of Intelligent Transportation Systems to increase the capacity of existing highway infrastructure, and **real-time pricing of transportation facilities.**

In urban environments pollution and congestion are becoming real social problems and many cities have started initiatives with the objective of reducing the levels of pollution and congestion through the limitation of vehicle access in the worst affected areas.

In the following, some solutions are described, discussed and compared. The most innovative approach, that could be the most efficient and acceptable from the user point of view, is then described in detail. This solution will be the basis of the Turin demonstration project.

OVERVIEW OF EXISTING APPROACHES TO CONTROL ACCESS IN URBAN AREAS

The main approaches currently used to control access to urban areas in order to reduce congestion and pollution are analysed below.

No access

During critical periods, in winter time, when heating systems contribute the most to city’s pollution levels and winds/rainfalls are scarce, a solution that has been used is to avoid completely vehicles’ circulation, with the exception of environmentally friendly vehicles (electric or natural gas powered). Given that the public transport system is at present not able to completely substitute the use of private cars, the scheme is believed to be acceptable only for non-working days, and therefore has been implemented only during Sundays.
Access controlled by vehicle type or plate

Avoiding the circulation of vehicles without catalyst exhaust systems in urban areas can produce a marked effect on pollution reduction with a minimal effect on the citizens’ mobility. An intermediate solution is to allow access to vehicles depending on their plate number (odd numbers on odd days, even numbers on even days). In spite of expectations, only a 20% of traffic reduction has been measured. This is due to “optimisation” of the use of the odd/even vehicles, within a family or group of vehicle owners.

Car Park Charging

In Turin and in many other cities, access to central or high traffic areas is also controlled by charging for car parking. This is done either by equipping parks with barriers and tollgates or by the blue line method: users have to pay by using parkmeters or prepaid tickets. This system influences the time cars spend in the controlled area, since the parking is paid for on a time basis.

Cordon Pricing

This approach implies that every vehicle entering the urban area has to pay a daily fee. In Bergen since 1986 private vehicles have been charged a flat fee for entering the city's central business district. The system operates between 6AM and 10PM Monday-Friday. Toll rings were subsequently also introduced in Oslo and Trondheim. A reduction of traffic up to 10% was registered during peak hours, balanced by an increase in off-peak hours. In the city of London, the road charging scheme started in February 2003. A fee of five pounds is charged per day. Preliminary results:

- Traffic reduction: 20%
- Daily fees paid: about 100,000
- Fine issued: roughly 20,000 every week

Traffic increase in the border zone of the restricted area has not been reported.

Electronic Access Control

A more flexible scheme has been in operation in Singapore since 1998. Cars are equipped with an ERP in-vehicle unit; when they pass under the gantries, the system identifies the vehicle and deducts the appropriate amount. Cameras enforce the structure. Charges are levied on a pay-as-you-use principle; differentiation is on the basis of day, time, type of vehicle, congestion level and place. Traffic volumes have been significantly reduced and the peak hour traffic has been spread slightly, since some vehicles took advantage of the lower cost sectors. High public acceptance was achieved.
Electronic Fee Collection on motorways based on satellite localisation

On German motorways, starting from 31 August 2003, trucks will pay 12.4 cents per kilometre. The fees will be collected by an on-board automatic toll collection system that combines mobile communication technology and GPS. The aim of the HGV toll charge is to establish a system on the "user pays" principle and to change from a system which draws its funding entirely from taxation to one which supplementary funding is draws also from transport operators. This distance-based charging system will replace the current time-based charging system ("Eurovignette") for HGVs.

A recent European directive is under discussion. If it becomes operative, by 2012 electronic tolling will be based on embedded Galileo-based telematics systems, and all tollgates will be removed over all Europe. The directive also recommends the use of this solution for managing/control the traffic in urban areas.

**PROPOSED SOLUTION: ELECTRONIC ROAD CHARGING IN URBAN AREAS**

The research project being undertaken in Torino aims to implement a real pay-per-use scheme over urban areas. The urban area is made up of infrastructure consisting of roads, car parks, limited access zones. Thanks to on-board devices, vehicles can be constantly always located during their movements in the city and monitored for use of the infrastructure.

Planned activities aim firstly to identify the key actors and their responsibilities, then the technical solutions required for managing the specific features of the urban road network. This kind of application requires the ability of the system to distinguish, without errors, ambiguous situations including: vehicles parked on the side of the street or standing in a queue, vehicles in the road or in a private car park behind the house gate, illegal parking and illegal access to restricted areas, use of the correct side of the road, etc; implying less than one meter accuracy in specific situations. These capabilities are based on accurate localisation techniques that must rely on satellite location systems used in conjunction with dead reckoning techniques and integration with road-side infrastructure for precision augmentation (e.g. beacon and/or transponders in critical sections). The effectiveness of the solution relies on the precision and suitability of the cartographic support. Moreover, this must be constantly updated to reflect variations in geometry, mobility, operating charging schemes, etc.

The ambitious goal of the research work will be to explore the use of the available and emerging technologies while responding to key requirements that makes the application really feasible:

- robustness and fault tolerance in any condition
- readiness for fraud control and enforcement
- low installation costs for final users
- low communication costs
- awareness of final users of the applied fare
- interoperability with other systems (e.g. while driving in other cities, etc...)
- confidence for the final user privacy

Key aspects and features addressed by the Torino demonstration project are described in the following sessions.
Selective demand management

This system allows a highly structured and elasticised method of payment and it is applicable to different strategies of demand management. Road payments could be determined on the basis of:

- **zone**: the city is split in different and variable fare zones;
- **day of the week, hour**: different periods are charged differently (e.g.: peak hours, week days);
- **time**: payment proportional to the time spent using the infrastructure;
- **distance**: fees are calculated over the number of kilometres;
- **type of vehicle**: private cars, trucks, etc. can be charged differently;
- **quantity of emissions**: one of the objectives is to reduce pollution…

Those criteria can also be assembled in complex schemes in order to tune an optimal solution.

Car Park charging

A combined fare structure for roads and car parks will allow a fair pay-per-use method. Parking could also be paid in a flexible mode (the less available are the places, the more they cost). An important issue is the precise distinction between charged parks and private parks, especially when they are closed to each other.

Furthermore, a good solution must distinguish a parked car from a running one, perhaps simply stopped close to a parking space.

Very precise localisation is hence needed.

The technology adopted

The overall architecture, which includes the two key components of the system: the central level and the on-board unit, is described in the figure. The distributed functionalities of the telematics system permit the segmentation of the urban areas (for access, transit or parking).

The system, using the localisation process (GPS/Galileo with dead reckoning and map matching techniques), can localise the vehicle relatively to the defined areas (outside, inside, on the border line). The information of position and other info (see section 4.1) are then stored in the memory of both the embedded system and the control centre.

The problem here is to achieve an optimal balance between embedded and infrastructure equipment, in order to minimise the overall cost, while assuring a perfect localisation and...
privacy of personal data.

The connection between vehicles and Control Centre is provided by a GPRS link, due to its high coverage and availability and use of bandwidth costs. Based on the transferred information, it will be possible to charge properly the user.

A key element is the installation of high-precision localisation equipment able to exchange information with a remote control centre. The experimental systems would use a combination of GPS/Galileo, dead reckoning and map matching techniques, using existing or ad-hoc solutions. The use of Galileo and, in the short term, of EGNOS localisation systems will bring important information, like the terrestrial augmentation and the integrity level data.

Location through the GSM/GPRS network will also be considered, as local augmentation, in order to guarantee the localisation also inside the urban “canyons”, where GPS satellites are not always visible enough to allow a precise computation of the position. Beacons, urban Wi-Fi nets and Digital Audio Broadcasting will provide local augmentation also.

In particular, the cartography represents an issue. On the one hand there exists very detailed urban land cartography, on the other there are good mobility digital maps, representing all the phenomena needed (private/public car parks, public transport, …). Since the latter are not detailed at the desired scale, an organisational effort will be made in order to merge the information sources to reach the desired cartographical support.

How to guarantee user privacy in a high localisation regime is an open issue. Methods range from cryptography to policies of data transfer from the vehicles. The data stored in the vehicle have to be preserved for a certain period of time, either for internal use (wrong data transfer), for user check (in case of controversial) and for public authorities use (police).

Enforcement will be guaranteed either by fixed or mobile control stations. The system will have a standard, like Bluetooth, dedicated short range communication (DSRC) capability. Through this DSRC a policeman could check a vehicle, comparing the info received through DSRC with license plate. In any case the info acquired (vehicle checked, position, time of the day) will be transferred to the Control Centre for further controls with the vehicle embedded system. Fixed (but transportable) control station, for example installed in parking vehicles, could also perform this enforcement function in a complete automatic fashion.

The challenge involves hence at least the following main obstacles:

- the integration of all these existing technologies;
- an optimal trade-off between on-board and central devices;
- the existence of a precise cartography;
- an ideal and inexpensive use of the telecommunications.
Private and public acceptance

Introducing new fare schemes is never painless, even when the method promises greater equity. Though a real and fair pay-per-use scheme should avoid fixed taxes, people are generally against this. A key to public acceptability is the transparent recycling of the collected money for new mobility infrastructures.

A policy has also to be adopted in order to ensure privacy: since the system will record the localisation of the vehicles, cryptography and masks have to be adopted.

From the point of view of the transport authority, one issue is enforcement. In order to ensure that in-vehicle devices are used fairly, policemen or ad-hoc personnel could be provided with DSCR equipment able to acquire the status from cars.

On-board and management systems must be robust and simple to use.

Testing the system

The field test will involve around 30 equipped vehicles over several months. The vehicles will be used for both testing the correct traffic monitoring and calibrating the payment methods. The aim is to achieve billing levels and costs comparable to the present system, but with much more flexibility and simplified organisation. Test Users will be chosen on the basis of their different features in terms of their urban mobility in order to reproduce a wide range of traffic patterns. In addition to normal testing the system will undergo any foreseen critical situation.

Interoperability and flexibility

The system will be able to work in any condition and position. It is tailored to urban areas, but can be used for non urban roads with less strict requirements and also works well for motorways, replacing existing methods like tollgates and Telepass.

In a transitory phase, integration and complementarity with the national scheme have to be assessed.

The equipment allows a series of value added functionalities. The list below gives a number of examples and is not exhaustive.

Parking payment could be made automatically by the system. User action is only required to control, since it is not always easy to distinguish, using the vehicle location, between public areas and private ones (this requires high accuracy in the vehicle location and the complete and precise map of the public/private areas, not easy to collect and maintain updated).

Traffic information: since all the vehicles will be equipped, the vehicles themselves could produce precise traffic information (floating car data).

Speed suggestion/warning: information on speed limits could be downloaded dynamically to the vehicles. Short-range communication could be used to suggest the optimal speed for each road segment (for example in order to reach the next crossing with green traffic light).

Benefits

The advantages of the application involve a number of different domains:

- Effectiveness in urban traffic control
- Collection of data inherent to mobility preferences
- Payments proportional to the use of the road infrastructure
- Reduction of public transport delays thanks to priority at intersections
- Reduction of road accidents thanks to traffic control
- Reduction of area pollution thanks to traffic and access control
- Reduction of travel times

Furthermore, industrial revenues will be remarkable:

- More effective and precise Automatic Vehicle Location (AVL) systems
- Solutions for secure and optimal communication
- Decision support systems and organisational solutions
- Friendlier human-machine interfaces
- Technologies for in-vehicle telematics and for service management
- Birth of new services and businesses

Finally, the acquired knowledge would benefit other sectors, like automotive service providers, tourism information, e-commerce.

In the intention of the project participants, moreover the results of this project should work as the launching platform also for a national (or even international) road charging schemes and/or pay per use car insurance adhering to the European trend. The added value of the project results deployment will be in adopting a solution which is already compatible with local systems ruling the mobility and the access to urban areas.

**COMPARISON AMONG “URBAN” SOLUTIONS**

The best solution is obviously the one which achieves the goal (traffic/pollution reduction under acceptable levels) and is preferred by the users. In order to compare the different solutions, at least in a very preliminary way, it is important to consider all aspects that could effect the user acceptability.

The following points have been considered:

- Traffic/pollution reduction in the restricted area
- Traffic effects in other areas
- Mobility constrains for the users
- Fixed Costs, for users
- Infrastructure cost. for public authority
- Variable Costs (once a day, per use)
- Extra cost (extra operation, like payment)
- Benefits (for user mobility)
- Extra benefits (services)

The solutions considered are:

- No access to restricted areas
- Partial access (even/odd license plate)
- Congestion charging
- Electronics Access control (with payment for every transit)
- Electronic Road Charging
The comparison shows the advantages of the proposed solution, with some drawbacks or points to be analysed:

- the traffic reduction will be proportional to the cost for the user.

The flexibility of the solution allows the implementation of very specific strategies. For example the cost could be higher if the route of the vehicle is in areas with very good public transport, in order to promote the use of public transport, without effecting the user mobility.

- the cost for the authority could be very high

If they have to pay all the on board equipments for the vehicles. On the other side the infrastructure cost could be very low compared with other solutions. The cost of the on board equipment, for public authority, could be reduced by the contribution of:

- the user;
- Application Service Providers that will use these devices to offer extra services to the users;
- the Government, since the device could produce also benefits in terms of Safety (emergency call)
- Insurance Companies, that could have less risks for vehicle thefts and the possibility to offer more personalised contracts (based on the vehicle use) to their customers.
PROJECT INFORMATION

The project will start in the beginning of 2004, it will be carried out over a period of 36 months and be divided into three main phases:

1. Feasibility and executive project - analysis of the subject, boundaries and strategies, requirements definition, design of the in-vehicle prototype equipment and project of the overall structure;

2. Realisation of a prototype – based on the first phase results, the vehicle equipment, a control centre and all the needed infrastructures will be realised. In addition, prototypes for supplementary added value services will be produced.

3. Analysis of the results and dissemination – the experimental system so far obtained will be validated through a wide range of tests. Results will be evaluated. It will be consequently defined how to promote and extend the system.

Torino Wireless Initiative

This research project is conducted in the framework of the Torino Wireless Initiative. The main aim of this initiative is to create conditions favourable to the development of new business and new enterprises in the Wireless sector. Torino has an environment favourable to the creation of new enterprises, thanks above all to its legacy of know-how and experience. It can therefore become a preferred location for creating and attracting enterprises, especially by introducing initiatives to stimulate and support new entrepreneurs.

The Torino Wireless Initiative intends to foster the creation of innovative businesses, the initiative goes in this direction making space available for the incubation of ideas, offering consultancy services and innovative forms of incentives and financing.

Furthermore the initiative will promote several research projects, funded by the National Minister of University and Research (MIUR), in order to strengthen the capabilities to produce innovation in wireless sector.

This project will exploit know how available in the Turin area in the field of Traffic Control (5T, CSST, Mizar), Wireless Communication (Telecom Italia Lab, Istituto Superiore Mario Boella), vehicle equipment (FIAT Research Centre) and Electronic Toll Enforcement (FATA Dts).
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Torino Wireless

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