Innovative Use of ICT for Urban Traffic Management

Marius IENCULESCU-POPOVICI, M.Sc.
Intergraph Computer Services Bucharest, Romania

Abstract: *Traffic congestion is a wide-spread disease of metropolitan areas. This article looks into some possible solutions to this issue based on innovative use of ICT, particularly in combining RFID technologies with geospatial and location technologies, together with traffic congestion tax policies and navigation services in order to create a mix of technologies and services, as well as revenue streams, bundled into a platform for managing traffic in congested urban areas.*

While each of the individual technological components of the proposed solution (geospatial information systems or GIS, RFID, vehicle navigation and location) is already an established technology, they have not been used yet in such a mix and with such a goal and in a city-wide environment because of several perceived obstacles:

- *Cost of RFID infrastructure for a city-wide infrastructure,*
- *Volume of data to be processed,*
- *Political sensitivity because of potential for abusing privacy of individuals and because of lack of popularity of new taxes.*

Acknowledging these major obstacles to a valid solution, this article proposes a new approach that has the potential to address such issues, bringing into the picture a possible financing mechanism based on revenues collected from a congestion+carbon tax that will be calculated individually for each car from traffic history generated by the very same system. Also, the use of RFID covering the entire city area, preferably with long range radio rather then short range, as a sensor system for calculating car position at any moment during traffic for each car in the city, could actually be the key to solving the traffic congestion issue, (albeit appearing to some RFID taken to extreme). If on top of this data collection system used for taxation and traffic management purposes, the drivers also receive valuable services, such as navigation and other location-based services, city officials may be able to "sell" such an idea to the general public and overcome the political hurdles inherent with the implementation of such a system.

Keywords: *intelligent traffic management systems, geospatial information systems, GIS, vehicle location, congestion tax, radio frequency identification, RFID, street navigation*

Introduction

Anyone living in mega-urban areas cannot avoid facing a major problem linked to people's need to move around within urban areas: congestion and traffic jams. And such traffic problems associated with urban mobility are not just a nuisance, but they generate negative externalities or marginal costs that are increasingly difficult for the society as a whole to sustain and afford:

- Excessive pollution that is a source of major health problems among city inhabitants and contributes with significant share to the global greenhouse effect, which again, in its turn, generates major climate changes that negatively affect the entire population;
- Substantial economic losses generated by time lost in traffic by city inhabitants;
- Increasing degradation of the natural and built environment alike within city boundaries, especially in downtown historical centers;
- Increasing number of traffic accidents and victims, as well as a steeping in socio-pathologic behavior among traffic participants etc.

City officials in areas plagued by traffic congestion have always used whatever means and technologies were available to them to address this issue, from policeman's whistles to traffic signals

controlled automatically by computers processing real-time traffic information obtained from traffic sensors or probes. In recent years, besides technology, city managers have increasingly resorted also to policy solutions aiming at changing urban mobility patterns: promotion of public transport and bicycles at the expense of private vehicles by investments in public transport infrastructure and bicycle lanes. Furthermore, cities like London, Stockholm or Singapore have turned to taxation implementing such taxes as downtown access tax or congestion tax, in their attempt to curb traffic congestion.

By introducing road usage or traffic related taxes, city administrators attempt to charge some of the marginal costs to those who actually generate them, namely drivers who chose to drive during rush-hours or through congested areas. Another effect of these policies is to slowly reverse the public's perception that road infrastructure in urban areas is a public and free good. Advocates of road tolls within urban areas expect that this will discourage abuse or overuse of the road infrastructure in the form of unnecessary car trips within the city. In their perception, traffic jams are primarily road network breakdowns stemming from the overuse encouraged by the users' belief that road access is for free.

On the other hand, those who oppose introduction of road taxation policies (be they road tolls, access fees, pollution tax or congestion tax) argue that there are many other methods to eliminate or at least alleviate traffic congestion:

- Improving and expanding, where possible, road infrastructure;
- Improving road signals systems;
- Eliminating free parking in congested areas in order to discourage drivers from driving around to find a vacant parking place;
- Taking a more serious look at traffic issues in urban planning processes;
- More severe punishment against those traffic rules trespassing behaviors that generate traffic problems (such as box-blocking);
- Reducing the time for repair works on the street when they affect the traffic, etc.

In practice, all such solutions appear to be fully effective only for a limited period of time, or at least over a limited area, until the traffic becomes unbearable again as number of cars inevitably grows due to demographics of mega-urban areas and steady decrease in price for new cars. In the opinion of the author of this article, in recent years some new developments have happened that present city officials with an opportunity to make a leap in the direction of solving traffic problems, if not to solve them for good:

- Two ICT technologies have grown mature: radio frequency identification of vehicles (known as RFID) and traffic modeling in GIS (Geographic Information Systems) software platforms,
- The issues of carbon pollution and greenhouse effect have climbed to the top of the public agenda, which has made the idea of introducing carbon taxes in urban area much more acceptable by the general public.

This article reviews several ICT-related solution tested so far in attempts to address traffic congestion and proposes a new approach, based on combining some of these existing technologies in a new formula, bundled with carbon taxation policies based on measuring actual car mileage in specific conditions.

1. State of the art

Whichever the solutions city officials turn to in order to solve traffic problems, they cannot ignore anymore the important role that ICT plays in this field. A very brief review of technologies that are currently applied in traffic control measures shows how wide the range of possible applications is:

- Street sensors for measuring real-time traffic conditions: closed circuit cameras, infrared sensors, electric loops, etc., able to measure with various degrees of precision the volume and speed of traffic in surveyed areas;

- Processing of mobile telephones location data to calculate average speed on certain streets, a method called Floating Car/Cellular Data – FCD;
- Automated control of street signals and restrictions based on inputs from sensors or even its simpler version which implies control by traffic controllers from a dispatch center based on information from street cameras;
- Complex IT systems for displaying and predictive modeling of traffic, based on GIS, mathematical models, and real-time plus historical traffic data;
- Decision-support information systems, similar with the above, but applied in decision making during urban and infrastructure planning processes;
- Personal car navigation systems and other ICT platforms for location-based information services provided to drivers in urban areas;
- Broadcast of current traffic conditions through dedicated radio channels as an input for personal navigation devices, a technology that is called Traffic Message Channel;
- Road toll or tax systems based on automated identification of vehicles using either radio technologies as RFID or video technologies such as camera-based Automated Number Plate Recognition (ANPR) or code-bar scanning;
- Several combinations of the above (such as automated street signal controlling based on traffic sensors inputs and predictive modeling of traffic in GIS systems).

Each of these technologies is already in operation in various cities around the world, usually within local government agencies, road authorities or even private operators involved in providing services related to driving. The following technologies and solution are of special interest to this discussion as they have proven very effective in addressing traffic problems:

1.1 Traffic measurement based on Floating Cellular Data (FCD)

The IT system of any mobile phone operator processes a significant volume of data that can be used to calculate the current traffic speed on a street segment. Basically, by either comparing the signal power difference or the time difference in the simultaneous communications between a single mobile telephone and at least three different based stations or cells, one can determine, with a certain precision, the position and the speed of a mobile telephone while it travels around the city. The latter method is widespread and is known as Time Difference of Arrival, or TDOA. Alternatively, position can be determined from handover data when a telephone passes from one cell to another. By aggregating TDOA or handover data over from all telephones in a certain area and applying certain algorithms meant to reduce possible errors, i.e. caused by the proximity of a street with a high-speed highway or a railway, and after eliminating telephone identity information the result is a data set that models with sufficient accuracy the traffic on a certain street. As traffic systems focus on traffic slow-down or jams, in which circumstance usually the number of telephones and callers increases in the affected area, increasing thus the accuracy of traffic measurement, the usefulness of this method is even higher for our purposes. Another advantage of this method is that it does not require investments in a dedicated sensor infrastructure as it takes advantage of the existing infrastructure for mobile telephones and the information of interest is a by-product of data generated for the core business of phone operators. Even if certain concerns related to potential for privacy abuse and unauthorized surveillance of telephone subscribers still prevails on the market, making certain phone operators rather reluctant to embrace this method, by the end of 2007 the majority of companies selling Personal Navigation Devices (such as TomTom) have started partnerships with mobile phone operators and brought to the market new versions of their devices that are able to use real-time data on traffic obtained from phone operators through FCD (GPS Business News, 2007).

The result of this method is the transmission of almost real-time data (refresh interval is usually in the range of few minutes) on traffic problems to PND terminals used in traffic by subscribers to this service, the proposed route displayed on the screen being thus much better adjusted to the current traffic conditions.

But real-time or almost real-time traffic data calculated by mobile telephone operators are not useful just to drivers when they make decisions regarding destination and route. All public agencies responsible for managing traffic and planning road infrastructure are natural clients of such information. In spite of this, by 2007 even the most advanced metropolitan administrations in utilizing IT for traffic management (such as London, Berlin, Beijing or Singapore) were still not using data from mobile phone operators as an input into their sophisticated traffic management systems, rather relying on street-sensors or traffic probes for this (Fraser, 2007). One should expect, nevertheless, that as FCD becomes more popular as a source of traffic data, the suppliers of predictive traffic modeling solutions for traffic management systems will open their systems to such data input sources.

1.2 Radio Frequency Identification of vehicles (RFID)

If in the case of the technological solution described above making data anonymous (i.e. extracting personal identity from processed data) is of critical importance, only the statistical result being relevant, in the case of identification technologies it is opposite: what is needed is precisely the data that uniquely identifies a vehicle. The RFID (Radio Frequency Identification) technology is likely to become the main automated vehicle identification method because, on one hand, it has an accuracy rate superior to Automated Number Plate Recognition (ANPR) – automated recognition of number plates from video information generated by street cameras and, on the other hand, does not require vehicles to slow down to be identified, as in the case of code bar reading methods.

Speaking in loose technological terms, there are no significant differences between how a vehicle is identified with RFID and how a telephone is identified in a mobile phone network. Except that with RFID the equivalent of the base station is a radio station with a much shorter range than a usual mobile phone cell station and uses another frequency range than those dedicated to GSM , CDMA, etc, networks. And instead of identifying uniquely a SIM card in a telephone, the RFID system identifies a much less sophisticated device, a *transponder* (short from transmitter-responder) that has no other functions than to respond with an identification signal when receiving a request from a base station. Automatic identification of vehicles is usually implemented in the context of tolling and taxation of road usage and the infrastructure is usually implemented in tolling stations on highways or on streets at the entrance in the taxed area of cities. Therefore, if we do not consider mobile phone networks to be proper RFID systems, then to this date there is no authority that has already implemented full coverage with an RFID system of an entire urban area. For this reason, current vehicle RFID systems generate statistic data that can be used only partially for measuring real-time traffic condition in spite of the fact that, theoretically at least, RFID technology could be just as useful for this purpose as FCD is, if it was implemented with the same geographic coverage.

As of now, the idea of fully covering a city with RFID with the purpose of generating data for traffic management is already announced on the market and we may just as well see a first implementation during 2008 in a project in China, in the City of Wuhan, which has a population in the range of 7 million people (VTT, 2007).

Also of interest to this article is the fact that the congestion tax system operatingl in Singapore, using an RFID platform for vehicle identification, is planned to undergo certain changes to be able to calculate taxes differently depending on the real traffic conditions (IBM, 2007). Once implemented, entering with your vehicle the taxed zone will cost you more during congestion hours, and the level of congestion will be measured through a combination of traffic sensors and a predictive model using historic traffic data (Land Transport Authority, 2008).

2. A new approach

Two of the concepts presented above, namely radio-based triangulation for estimating vehicle position and speed as well as radio-based identification of vehicles, could be combined in a single system of sensors, with a full coverage of the metropolitan area. Some small changes in how current technology is used are still needed:

- Identification stations (the radio readers) need to be stronger (i.e. with a wider range) than usual RFID stations in order for an authority to be able to build a network of readers with full metropolitan coverage using a reasonable number of installed equipments;
- System developers will have to design what specific data needs to be stored on and transmitted by the radio tags placed on vehicles (the transponders), as well as the methods necessary for the system to calculate vehicle position (most likely similar to the TDOA method used in mobile networks to calculate position of telephones) and also the algorithms for statistical adjustment of individual vehicle positions needed for obtaining a reasonable error rate in traffic measurement;
- Authorities implementing such a system will have to develop terminals that combine the functions of a radio tag (or transponder) with those of a Personal Navigation Device, terminals that need to be installed on all vehicles entering the area covered by the system.

Once these changes or extensions are operated and the system is implemented, data that is generated by this radio infrastructure becomes input for three different information systems that make up the proposed integrated platform for traffic management:

- A geospatial information system used for visualizing the traffic problems in a digital map interface, for predictive modeling of traffic, as well as for automated control of traffic signals, street lights and restrictions systems; we refer here to dynamic modeling systems that are able to process sensor data fed in continuously by the RFID system;
- A toll/tax system for road usage and carbon emission that will calculate tax based on individual mileage data for each vehicle, with the capability to tax differently depending on specific traffic conditions recorded for each distance;
- A platform for providing drivers enrolled in the system location based services, such as navigation, parking orientation and booking, etc.

In practice, such a combination of technologies and public policies that build on each other will lead to:

- An intelligent traffic management based on real or almost real-time data collected city-wide (not just in certain areas, as it is the case with current systems);
- Road usage and carbon emission taxation based on an algorithm that takes into consideration real traffic conditions that influence emissions and real mileage on roads;
- Provision of navigation and location services, including real-time traffic information, to all vehicles in traffic;
- Funding of the traffic management system from the revenue stream generated by taxation and/or services provided over the platform itself.

An alternative setup to the proposed solution is to install universally (i.e. on all cars) only the radio tag and to integrate in the system navigation and other location-based services only for those drivers that opt for it (as opposed to universal inclusion of the location and navigation services in the platform). Obviously, this would require commercially available personal navigation devices with the capacity to utilize dynamic traffic information provided by the road authority. While it is true that this alternative scenario is theoretically more feasible because it does not imply for the public administration to take over a role already well covered by private companies, on the other hand it has the disadvantage that not all drivers will receive traffic orientation information. This in turn will decrease the efficiency of the traffic management system, as it will have to work like an incident-solving system (i.e. signaling cars out of traffic jams) instead of an incident prevention system (i.e. helping drivers to avoid congested areas).

Conclusions

The proposed scenario does not involve major technological innovations or fundamental research. However, its institutional feasibility still has to be tested, given that certain institutional issues could threaten the implementation of such a system:

- The main stakeholder that needs to assume the design, implementation and operation of the system is local government and traditionally this type of organizations are not very good at bringing projects of this level of complexity to successful completion;
- By implementing such a system, the public administration from a certain city enters into competition with private service operators, even if only on a specific market like car navigation services and only in a limited geographic area; general wisdom has it that such situations should be avoided and government should focus on traffic management exclusively, leaving to private operators the service providing part;
- The financial feasibility of this system, but also one of the reasons to invest in it, is linked to introducing a new tax, never a popular thing to do, which would understandably make any local government in the world very shy about proposing and adopting it.

But none of these issues seems impossible to tackle and it is not hard to imagine a moment in the near future when the marginal social costs of traffic congestion and pollution in a metropolitan area will be too high for the community to sustain them and when the other non-technological and non-fiscal methods will fail to sufficiently alleviate the problem. Then, such a mix of technology and policies as presented here might just as well become reality.

Bibliography

1. **GPS BUSINESS NEWS** (2007) ”TomTom Launches Traffic Information Based on GSM Data”, http://www.gpsbusinessnews.com/index.php?action=article&numero=493, retrieved on May 8, 2008

2. **IBM** (2007) ”IBM and Singapore's Land Transport Authority Pilot Innovative Traffic Prediction Tool”, http://www-03.ibm.com/press/us/en/pressrelease/21971.wss, retrieved on May 8, 2008

3. **LAND TRANSPORT AUTHORITY** (2008) ”Electronic Road Pricing”, http://www.lta.gov.sg/motoring_matters/index_motoring_erp.htm , retrieved on May 8, 2008

4. **FRASER, SCOTT** (2007) *The Use of Floating Cellular Telephone Data for Real-Time Transportation Incident Management*, McGregor University, available online at http://msep.mcmaster.ca/publications/FloatingCellularTelephoneData.pdf

5. **VTT** (2007) ”New long-range RFID technology from VTT for Chinese road tolls”, http://www.vtt.fi/whatsnew/2007/20070329.jsp, retrieved on May 8, 2008