REAL TIME CHANGES OF ROAD NETWORK TOPOLOGY AS AN APPROACH TO MITIGATE THE EFFECTS OF INCIDENTS IN URBAN CONGESTION

Rute Geraldes, Instituto Superior Técnico (IST), rutecg@civil.ist.utl.pt

José Manuel Viegas, Instituto Superior Técnico (IST), viegas@civil.ist.utl.pt

ABSTRACT

Noting the importance of incidents in urban congestion and looking for ways of reducing their impact, and after review of past efforts in this area, it has become clear that major efforts have a common idea, giving information about the incident and network status to the drivers. But after a first promising and good acceptance phase of the idea, recent reported experiments and studies seem to show that practical results are not as good as expected. This is due mostly to two facts. First, the information has no value if there aren't alternative paths because the network has no extra capacity. Second, the drivers use the information in their own best interest to achieve a user optimum, which is known to be different from the system (network) optimum.

This paper reports on an alternative approach. We assume that the technology is available to achieve almost perfect information on the state of the road network in real time, as well as on variable message panels that allow variable signs or messages of any kind (text or picture), and with this we treat the road network as other kind of networks where the external shape (morphology) is fixed, but the topology can be changed. Variable message signs permit us to change the way (direction of flow) of the streets and turning prohibitions in a similar way to what switches and valves do in other kinds of networks. So, in general, we admit that when a disrupted situation occurs, the topology of the network may be changed to facilitate relief.

In order to test the hypothesis that changing the network topology can be a solution in the cases that information to the drivers is not sufficient and facing the impossibility of testing it in reality, the simulation software Aimsun was utilized to simulate for several traffic scenarios, three possible reactions to incident situations: no intervention, distribution of information to the drivers, and topological changes in the network along with the distribution of information.

Simulation results are presented and discussed in this paper together with a *more detailed explanation of the hypotheses.*

Keywords: Traffic Incidents, Urban Road Congestion, Network Topology, Simulation

INTRODUCTION

Congestion is today a big problem for almost all large cities. Very often congestion doesn't occur only because of a known excess of demand (peak hours) but because of sudden reductions of supply caused by incidents like traffic accidents, immobilized vehicles or other kind of temporary obstacles. There is a large amount of study and discussion on the first case, and rather less on the second and that is what we propose to do here.

Nonrecurring events, such as incidents, weather, work zones, and special events, cause more than half of all traffic congestion, according to the FHWA Office of Operations (see Figure 1). (Helman, 2004)

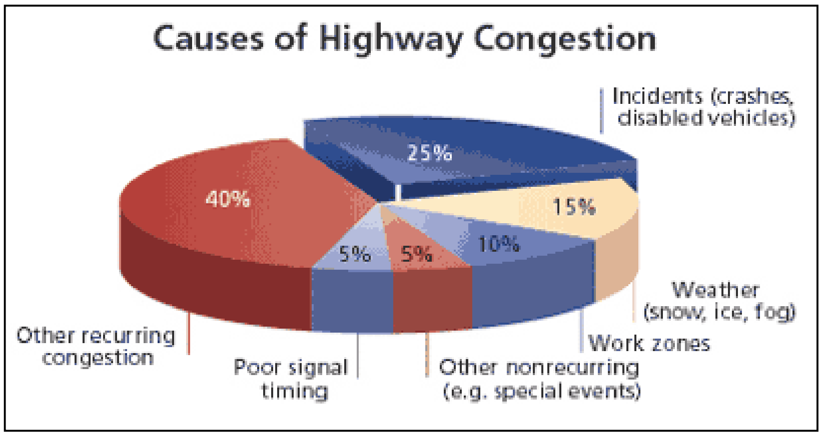

Figure 1 – Relevance of Incidents in congestion. (Helman, 2004)

Although the congestion problem derived from incidents is better studied for highways, a study from Texas Transportation Institute, on urban areas, demonstrate that the problem is also big in urban environments, as it reports that 52% to 58% of total delays are caused by incidents. (Schrank & Lomax, 2009)

If we note that recurrent congestion can be accommodated by drivers in their scheduling planning, but they can't predict an incident and its consequent delay, the same delay is more problematic for the drivers and seems bigger in their eyes when deriving from non recurrent then when deriving from recurrent congestion.

When the goal is to solve in the immediate congestion problems resulting from temporary and non recurrent causes the solution necessarily has to be obtained with the existing infrastructure.

BRIEF SURVEY OF EXISTING APPROACHES

The purpose of this chapter is to transmit that since the problem has been defined (congestion caused by incidents in urban roads) searches for ideas to tackle it have been conducted mainly in two different groups of works:

- works devoted to solving congestion in general. Taking into account the specificity of the non recurrent congestion problem, here the focus was clearly on

Intelligent Transportation Systems (ITS) because by definition they try to take maximum efficiency from the existing transportation infrastructure.

- works devoted to recovery of failures in other kinds of networks, with particular focus on those solutions that require network features similar to the ones from road networks.

What is described here are the personal perceptions, from what has been revised, building on the sequence of thoughts leading to the formulation of the approach and the hypothesis to be defined in this presentation.

Intelligent Transportation Systems

> "ITS combines high technology and improvements in information systems, communication, sensors, and advanced mathematical methods with the conventional world of surface transportation infrastructure". (Sussman, 2005)

This statement by Joseph Sussman really summarizes that ITS is all about taking advantage of technology to improve existing transportation systems in a variety of areas and for a variety of agents. In spite of some implementation issues that ITS have been facing (deriving more from other kind of problems and less from technology limitations), technology and science fields, because of its evolutions (particularly in the areas focused by Sussman), are no longer constraining most of ITS implementations.

Table I gives some examples of the technologies available.

Table I - Enabling technologies. (PIARC Commitee on Intelligent Transport, 1999)

ITS Enabling Technologies	Infrastructure Side	Vehicle Side
Data acquisition	Traffic detectors	AVI
	Weather monitors	Weigh-in-motion
Data processing	Data fusion	GPS
	AID	Digital map
Data communications	Stationary communications	Mobile communications
	Fiber optics	DSRC
Information Distribution	VMS	HAR
	Internet	RDS/TMC
Information utilization	Ramp Metering	Route Guidance
	UTC	Crash avoidance

AID = automatic incident detection
AVI = automatic vehicle identification
DSRC = dedicated short-range communications
GPS = global positioning system
HAR = highway advisory radio
RDS/TMC = radio data system/traffic message channel
UTC = urban traffic control
VMS = variable message sign

The International Organization for Standardization (ISO) has standardized the taxonomy of ITS user services, this is possible ITS applications, like shown in Table II.

Table II – Users services. (PIARC Commitee on Intelligent Transport, 1999)

Traffic management	Transportation planning support Traffic control Incident management Demand management Policing/enforcing traffic regulations Infrastructure maintenance management
Traveller information	Pretrip information On trip driver information On trip public transport information Personal information services Route guidance and navigation
Vehicle systems	Vision enhancement Automated vehicle operation Longitudinal collision avoidance Lateral collision avoidance Safety readiness Precrash restraint deployment
Commercial vehicle	Commercial vehicle preclearance Commercial vehicle administrative processes Automated roadside safety inspection Commercial vehicle on-board safety monitoring Commercial vehicle fleet management
Public Transport	Public transport management Demand-responsive transport management Shared transport management
Emergency management	Emergency notification and personal security Emergency vehicle management Hazardous materials and incident notification
Electronic payment	Electronic financial transactions
Safety	Public travel security Safety enhancement for vulnerable road users Intelligent junctions

From these applications, the ones that could possibly bring something to the solution of our problem are those from traffic management and traveller information fields.
From Traffic Management because traffic management systems ensure that road network capacity is used to its maximum and that is a concept that fits in an approach to the present problem. But on one hand, works focusing in Incident management are mostly directed to Incident detection, physical elimination and emergency assistance and not to managing its consequences in terms of congestion and on the other works dealing with congestion

problems never direct ITS for the resolution of the particular problem of non-recurrent congestion.
From Traffic Information Systems because, unlike the former, they have been pointed as beneficial systems for traffic under incident conditions.
Advanced traffic information systems (ATIS) give information about current traffic state conditions so that travellers are better informed when making decisions like mode or route choices and the underlying idea is that by using this information in their own advantage travellers also improve the transport system efficiency.
Contradictory studies can be found on this subject. Some point to benefits to the road network from the use of ATIS, others on the contrary point to inconveniences caused by overreaction phenomenon. Some defend that the over-reaction phenomenon can be eliminated by providing predictive information instead of current information, others show some cases in which even with predictive ATIS the benefits for the network are almost none.
Clearly although ATIS can be beneficial in some cases it is not the solution for all the situations.
The information chain through which ITS deliver needed services to the users has a structure like the described in Figure 2.

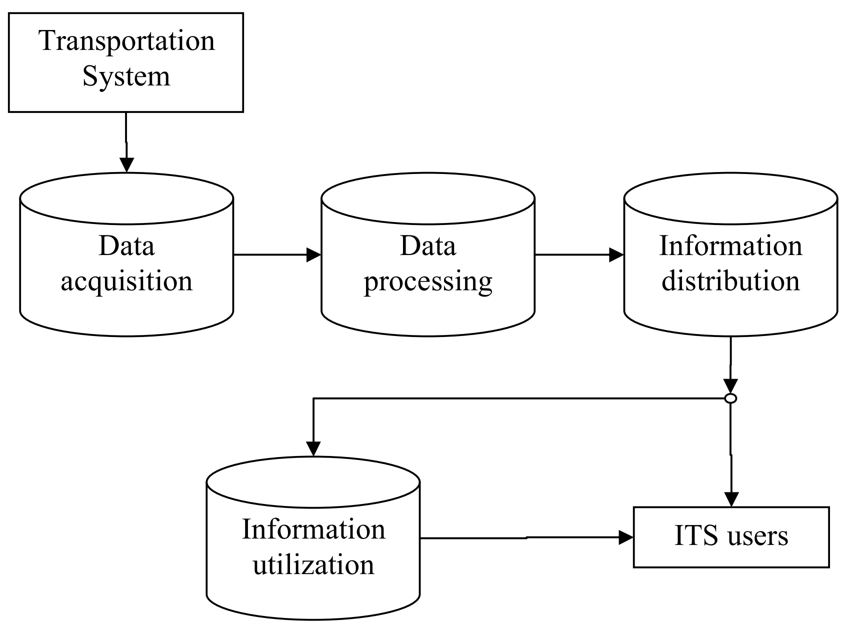

Figure 2 – ITS information chain. (PIARC Commitee on Intelligent Transport, 1999)

Network Recovery Problems and Solutions

Taking a look at works about failures recovery in distribution networks, it can be found a common idea to some of them: operate switches and valves (or other kind of equipments in the nodes of the network) re-routing the flows (under a new topology of the network), in order to restore entire network or at least minimize the affected part of the network.
It is interesting to note that some of these distribution networks, for example water and electricity, have fixed physical infrastructures (morphology) like road networks, but they still

are able to change their topology, by means of equipments located in the nodes of the network, that control the use of the sections departing from those nodes.
(Salazar, Ramón, & Romero, 2006) is just an example of it.

APPROACHING THE PROBLEM OF MITIGATING THE EFFECTS OF INCIDENTS IN URBAN CONGESTION

Operationally thinking, from the point of view of the entity responsible for the urban road network management, a good intelligent incident management system would have a basic structure incorporating a chain similar to the information chain from general ITS from Figure 2.

A good intelligent/advanced traffic incident management system (ATIMS) has to incorporate the following steps:

- Incident Detection – A good Incident detection system is vital because only with a quick alarm can a quick intervention be triggered and longer times of accumulation of vehicles in the surrounding area of the incident can be avoid.
- Getting a picture of the existing situation – This picture together with the incident information compose the problem inputs. It is easy to understand the importance of this step because solving a problem to the wrong premises is not solving the real problem and might even be detrimental.
- Understand how to intervene, selecting the best strategies for the detected situation - Several kind of strategies, to be applied together, must be attained:
    - *Incident dissipation strategy (if needed)*
    - *Emergency assistance Strategy (if needed)*
    - *Traffic Management/Control to Congestion minimization Strategy (if needed)*
- Intervene – Take the necessary actions to apply defined strategies
- Monitor, readjust and learn for future situations – The big difference from road networks to other kind of distribution networks is in the flows to be re-routed, as in this case the “particles” have their own will and their behavior through the network cannot be deterministically predefined. The human factor many times confuses the situation. For this reason and for learning proposes the work doesn’t end once strategies are applied and there is the need to monitor.

It is our conviction that from all the fields involved in the above described system the one that simultaneously is actually less studied, presenting more deficiencies and in which improvements would have the biggest impacts, is the Traffic Management/Control to Congestion minimization Strategy. Focusing on it and taking into account what has been said in the survey of existing approaches, an idea has been developed: apply the usual ATIS whenever it is enough to produce a good impact, but when it is not (what often happens mainly because there is no free capacity in the network and/or because of the difference between user optima and system optimum) change network topology, similarly to another types of networks, to a configuration that, together with ATIS can minimize the congestion caused by the incident.

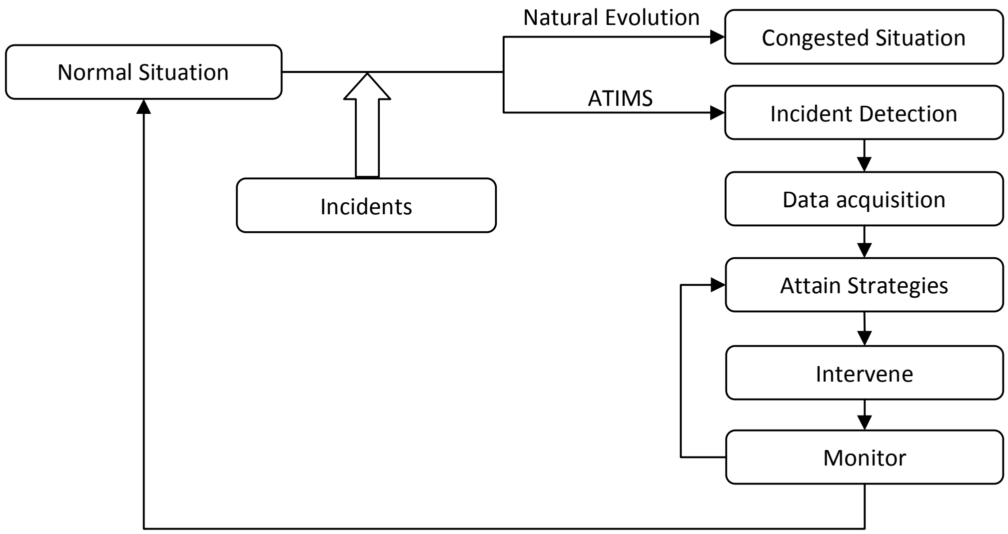

Figure 3 – An ATMIS structure

The concept of real time topology changes

Some review work made possible to assume that the technology is available to achieve and transmit almost perfect information on the state of the road network in real time, as well as on variable message panels that allow variable signs or messages of any kind (text or picture), and with this we treat the road network as other kind of networks where the external shape (morphology) is fixed, but the topology can be changed.
Variable message signs located at intersections allow that signals regarding street ways and turnings obligations and prohibitions can be changed in real time, permitting us to change the way of the streets and turning prohibitions, in a similar way to what switches and valves do in other kinds of networks, from a remote point and in real time.
So, in general, we admit that when a disrupted situation occurs, the topology of the network may be changed to facilitate congestion relief.

Hypothesis

At this stage a hypothesis to be tested has been formulated: Correct network topology changes, together with an ATIS, can perform better than ATIS alone, in those situations where ATIS by itself doesn't have a good performance in the task of managing traffic incidents congestion impacts.

TESTS TO RUN

In order to test the defined hypothesis tests must be conducted accordingly to the methodology defined in (Geraldes & Viegas, 2010).

First different incident situations were created and the methodology was applied on a small conceptual test network. The objective, for each incident case, was to get the following data:

- Network performance measures, for the period in which incident effects are felt, for normal situation (without incident) and incident situation without ATIS or ATIMS. This shows how the network is affected by the incident.
- Network performance measures for the period since the incident is detected until incident effects are no longer felt in the incident situation without ATIS or AMIS. This has to be measured for the incident situation without ATIS or ATIMS, for the incident situation with ATIS and the incident situation with ATIS and network topology changes, allowing their comparison.

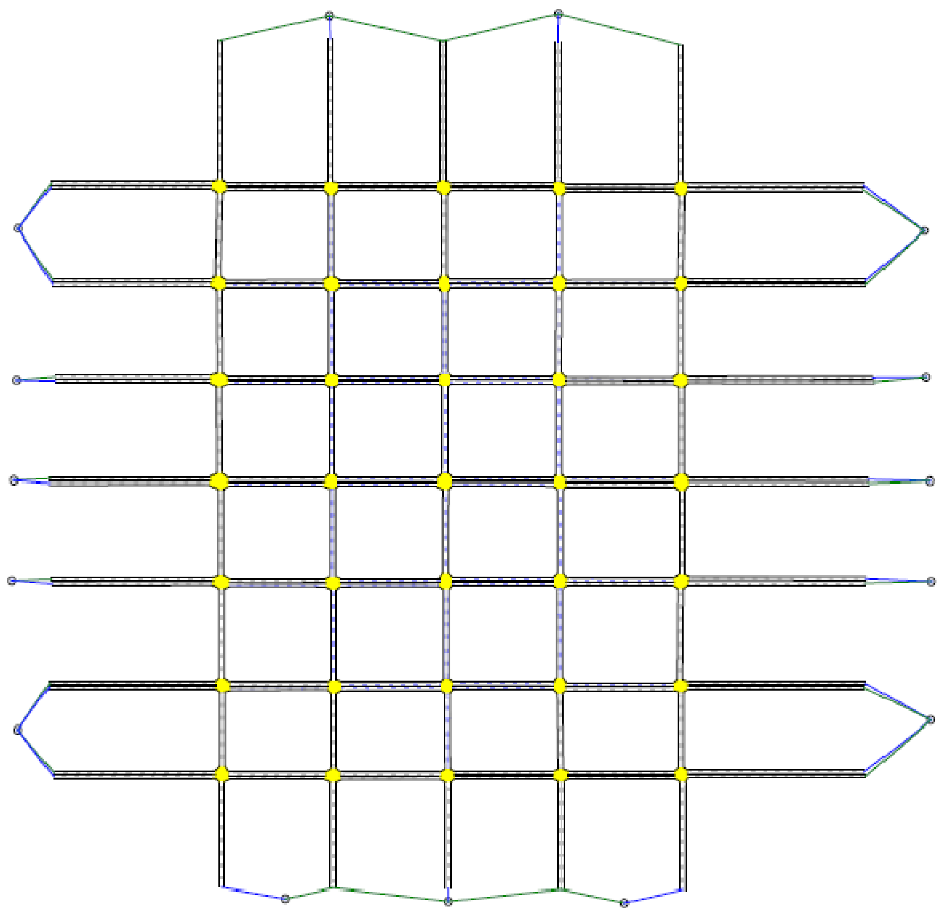

Figure 4 – Aimsun image of the conceptual network utilized in tests

Trying to recreate real conditions, as far as available data allowed it, a part of Lisbon network was described in order to conduct similar tests to the ones conducted to the first network.
The data available is not precise enough to allow us to say that the results apply to Lisbon real case, but the concern was to test our hypothesis under conditions that are realistic enough.

Figure 5 – Aimsun image of the part of Lisbon network to be utilized in tests

RESULTS AND CONCLUSIONS

At the time to deliver this paper tests still running, results will be announced during corresponding conference presentation.

REFERENCES/ BIBLIOGRAPHY

Geraldes, R., & Viegas, J. M. (2010). A methodology to estimate possible gains from real time changes in road network topology. *12th World Conference on Transport Research .* Lisbo .

Helman, D. L. (2004). Traffic incident management: clearing incidents safely and quickly requires an effective traffic incident management program 24 hours a day, 7 days a week. *Public Roads Nov-Dec* .

PIARC Commitee on Intelligent Transport. (1999). *ITS handbook 2000, recomendations from the world road association (PIARC).* Chen, Kan; Miles, John C. Miles.

Salazar, H., Ramón, G., & Romero, R. (July de 2006). Artificial neural networks and clustering techniques applied in the reconfiguration of distribution systems. *IEEE Transactions on power delivery, vol.21, nº3* , pp. 1735-1742.

Schrank, D., & Lomax, T. (2009). *Urban mobility report 2009.* Texas Transportation Institute.

Sussman, J. M. (2005). *Perspectives on intelligent transportation systems.* Springer.