An introduction to PACSIM: a new dynamic behavioural model for traffic assignment

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PACSIM: a new dynamic behavioural model for multimodal traffic assignment

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Abstract

The present paper provides a brief introduction to PACSIM, a new model for multimodal traffic assignment. This model is distinguished by the introduction of several important features: full dynamism based on an event-driven paradigm, complete modelling of the network of information provided to network users, multilevel network representation, multimodal capabilities and the use of an explicit parametrisable behavioural theory. The paper discusses the main motivations and design concepts and presents an illustrative application of PACSIM to advanced incident warning. Some perspectives are finally outlined.

1 Introduction

Asserting the usefulness of traffic assignement models has become a very commonplace argument over the past twenty years, but it is only comparatively recently that the need for complex dynamic models has really emerged (see Ben-Akiva (1985)). This need is correlated with the desire to study the impact of various advanced information systems for network users. These systems propose to improve the congestion levels in large urban areas by providing timely and accurate information to the drivers (Ben-Akiva *et al.* (1992), Arnott *et al.* (1991), Watling and van Vuren (1993)). Since classical equilibrium type models typically assume that the user's information is complete, accurate and timely, the new proposals seemed to be irrelevant for their application, which, in turn, highlighted the inherent strong assumptions of such models (for instance, see Dehoux and Toint (1991) for a deeper discussion of this subject). A major research effort resulted world-wide, whose purpose was and still is to build traffic assignment models in which these asssumptions of perfect information are absent.

Developed partly with the support of the IMAURO project during the DRIVE I European program and partly with the support of the impulse program "Transport and Mobility"(Services of the Belgian Prime Minister), the PACSIM model can be considered as one of the attempts to build traffic assignment models in which the assumptions on the information available to users and on the actual behaviour of these users are relaxed and brought closer to reality. The main purpose is to provide a sensitive traffic modelling technique which could then be used to assert the qualitative effects of advanced driver information systems (ATIS[1] in the USA, ATT[2] in Europe). It is not our purpose here to describe the PACSIM model in detail (a preliminary detailed description may be found in Dehoux *et al.* (1990)). We instead concentrate on some of the modelling concepts, with the aim to show how these are correlated with the major design challenges in this area.

2 A few desirable model features in the ATIS/ATT framework

When thinking of models adapted to assess the impact of advanced users information systems, it seems natural to search for directions and features which would make such tools viable. We now examine some of these.

2.1 A dynamic nature

Because much of ATIS/ATT is geared at the dynamic behaviour of transportation users and at the control or analysis of transient phenomenons, dynamic transportation models seem unavoidable within this context. Network users indeed have clearly different strategies in peak hour as opposed to off-peak, in week-ends as opposed to week days, in day as opposed to night, and the list of examples can easily be made longer. Furthermore, techniques like intelligent incident detection and interactive or automated route guidance are only meaningful in a dynamic context, as they involve "en-route" modifications of the user's route, which is totally impossible to represent with static approaches.

It is remarkable that, although appreciated by many experts, this conclusion has not always been applied in its full requirements. Because of the difficulty in building intrinsically dynamic models, static models whose parameters were made dependent on time have often been used. Whether this methodology is in fact coherent is clearly questionable, and heavily depends on the other factors in the chosen methodology. The crucial question is in the manner in which information (traffic or other) is propagated along the time dimension and the assumptions made on this propagation. But modellers and model users interested in ATIS/ATT should bear in mind that it isn't usually enough for a model to depend on time to become a truly dynamic model.

2.2 A flexible and standardized behavioural mechanism

In transportation models, the notion of global cost associated with displacement is typically taken into account by the choice of a *cost function* or *performance function* that determines, for each link of the network, a "cost" as a function of the traffic on that link. Units for this cost vary from model to model, and are chosen in relation with the final purpose of the modelling. For example,

[1]Advanced Traffic Informations Systems.
[2]Advanced Transport Telematics.

the quantity of exhaust gas of a certain type can be used if one wishes to measure the pollution impacts, while transportation time can be used if one is interested at asserting the level of service of public transport... There is however a remarkable consistency between all these choices, irrespective of the units chosen: the cost function is typically increasing as traffic along the link increases, slowly first but faster and faster for higher traffic levels. For example, the travel time along a link is relatively independent of traffic for low traffic levels, but can increase substantially for more congested levels, up to the point where not a single vehicle can move because everybody is stuck in a traffic jam!

It should be noted that the choice of a single performance function associated with the parts of the transportation network implies a complete and uniform rationality of the users in the measure where each user minimizes his or her disutility. This assumption has often been criticized as irrealistic. One way to overcome the difficulty is to introduce some degree of stochasticity in the users' choice criteria. Finally, optimizing a single "utility function" (even containing some stochastic component) often raises the question of comparing various goods or services of qualitatively different nature, a very difficult task. For instance, it is often necessary to estimate the monetary value of time (VOT) for users or users' classes. Some concepts in multi-objective optimization (see Yu (1989) for a good introduction) could present an interesting alternative at this level, but this approach is not widely used (see de Palma *et al.*, 1990 for an example).

The use of utility function within the ATT framework has its supporters and detractors. The main arguments in favor of this approach are

- the possibly high disaggregation level allowed by the methodology,
- the easier calibration of the resulting models (at least for moderate disaggregation levels) compared to other alternatives,
- the existence of good related mathematical and software tools (see Daly, 1987 and Bierlaire, 1994).

Arguments that have been used against the technique are as follows.

- The behaviour of humans cannot be safely represented by the optimization of a utility function, mostly because many users do not know their utility function and also because they are, in complex cases, mostly unable to perform a proper optimization, especially when the decision process is quick as it is in traffic.
- The variation of perception among users' classes is badly represented by assuming random variations.

These considerations have led to modelling systems where behaviour is not represented anymore by the optimization of utility function, but by application of adapted *behavioural rules*. These rules are not assumed to reflect the (undetermined) rationality of the user, but are just considered as *descriptive* of behaviour, as opposed to resulting from deeper processing. This kind of approach is clearly very inspired by artificial intelligence techniques, where the inadequacy of utility functions has often been pointed out. This rule-based paradigm is very attractive in many ways (at least to the authors) but present the difficulty of the necessary statement sufficient and meaningful rules. This is a very difficult task, mostly because relevant behavioural theories are still very much in the development stage, and certainly no general agreement has been reached as to which theories do best represent the behaviour of network users in what are potentially extremely diverse situations. Therefore, there seems to be little point in incorporating one particular behavioural theory in a traffic model, and exclude other promising approaches at the same time. New models should therefore provide the capacity to use a particular *behavioural theory as a model parameter*. Furthermore, as several theories are likely to be of interest, the specific way in which models handle behavioural theories must be extremely flexible and adaptable.

Several possibilities exist to fulfill these goals, ranging from parametrized cost functions (probably too restrictive) to complete representation of the theory using knowledge representations systems, as developed in the area of artificial intelligence.

The authors believe it is important that efforts are made towards a coherent way to represent behavioural theories, hopefully leading to some *standardization* in this research area. Furthermore, the representation format should allow simple and error free transmission to other researchers and, in the best case, be directly exploitable as such by modelling programs. These requirements are indeed crucial for these theories to play a really practical role in modelling methodology, even if they now appear to be somewhat idealistic. We refer the reader to McArthur (1991) for a discussion of a potentially useful approach.

2.3 A behaviourally coherent traffic metaphor

The specific constraint on aggregation level appearing in the ATIS/ATT context is that of behavioural coherence. As is clear from above discussions, the modelling of the transportation system in this context imposes that special care is given to user's behaviours, both in the short term (in immediate decision making like en-route choice) but also in the longer term (attitudes). It is therefore important to base the models on a metaphor that provides this behavioural coherence.

It is quite difficult to think of a behaviourally coherent transportation flow, for instance, because the idea of flow implies some kind of uniformity in the pattern, leaving no room for differences within the flow. Although one could think of models describing the flow of several fluids together, this remains, to the authors' knowledge, rather speculative. One is therefore naturally led to more disaggregate metaphors, involving groups of users with similar behaviour. Many such metaphors have been proposed at a meso level, as *platoons* or *packets*. They are adequate for ATT sensitive models in direct measure of their behavioural coherence. The situation is finally most complicated when considering ATT sensitive public transportation modelling, since, in this context, the only reasonable "unit" seems to be the individual user, which directly leads to micro-models.

As a consequence of this discussion, it seems that, in first approach, micro-models are more adapted to behaviourally coherent simulation. Unfortunately, micro-models tend to be more limited in spatial coverage, because of their intrinsic higher complexity. There is therefore a need to develop meso-models whose spatial coverage can be much wider but whose behavioural coherence has to be specially emphasized.

2.4 A flexible network representation

A very flexible transportation network representation is also extremely desirable in our "behaviourally driven" methodology. Indeed, users can only decide on route and mode choice within the framework of their knowledge of the network. But one knows from the research in mental maps (see Downs and Stea (1977)) that this knowledge might present relatively severe distortions from reality. It also typically involves some level of network abstraction (only major links are perceived in distant or unfamiliar districts).

The behavioural route or mode decision can then be broadly split into two phases (see Ben-Akiva *et al.* (1992)), both driven by behavioural theory: the user knowledge is asserted first, followed by some choice between the decisions that are possible in the restricted context of this knowledge.

It is therefore crucial that the network representation can easily be adapted and modified (according to a given behavioural theory) to better reflect the user's perception of the network. This modification will thus typically involve network abstraction and distortions of various types (link suppression, cost modification, preferred routes, ...). This requirement in turn imposes the use of specialized and flexible data structures.

2.5 The information network

The impact of new advanced technologies in transportation has an important consequence on the spatial description of models. The main observation is that the object of study is no longer restricted to the movements of users in the transportation network, but also covers the exchange of information across its various parts: sophisticate route guidance or incident detection as well as relatively classical traffic light synchronization involve that exchange very clearly. Furthermore, the efficiency of advanced ATT is often said to be dependent on the quality, reliability, accuracy of the exchanged information, and on its distribution method.

Typical examples of relevant factors are

- the location of traffic monitoring equipment (the actual locations of detection and measurement equipment on the network of course condition the final information in that it specifies the parts of the network about which information could be available),
- the location of information distribution mechanisms (conditioning in turn the locations at which re-routing can occur),

- the accessibility of information (defining the classes of network users accessing possibly different types of information),
- the strategies used to process information from the network before subsequent redistribution to users,
- the actual interconnection pattern (topology) of monitoring devices, information processing centres and distribution mechanisms.

Besides the classical transportation network, we therefore discover another network, which describes the information flow (the feedback loop) between the transportation network and its users. We call this network the *information network*. It is the authors' view that explicit modelling of this information network is an important part of the present research challenges in this area.

Of course, these information network models should be flexible, in order to adapt to the many different cases of potential interest. In particular, they should include the relevant factors mentioned above, but also parameters that influence their efficiency (communication links' or detectors' reliabilities, for instance) and thus also permit the modelling of information system breakdowns.

3 The PACSIM approach to behaviourally driven route choice and assignment

After reviewing some desirable features for ATIS/ATT sensitive traffic models, we survey some of the modelling choices that were made for the traffic model PACSIM in compliance with our above comments.

3.1 The handling of time

As discussed above, an explicit time dimension is also recommended for the type of models we have in mind. PACSIM is thus a dynamic model: it is event driven in the sense that the passing of time is viewed as the succession of a number of *events*. These events are, within PACSIM, of two distinct natures. The first type of event is associated with true physical event happening in the transportation network itself, as occurrence of congestion or bad weather conditions, traffic light changes, arrival of cars at intersections, road works or traffic accidents. The second type of event is associated to the transfer of information throughout the information network: detectors actuation and information transmission across the communication network (including the specification of delays and information life-time). These two types of events are then scheduled within PACSIM, according to parametrized priority rules[3].

3.2 Modelling the information network

We also stated above that an explicit model of the information flow from the network to its users is desirable. In accordance with this suggestion, PACSIM

[3] Most of these rules give priority to "physical events" (such as accidents of traffic light changes) on decisions taken by users (route changes) at the same instant.

contains such an explicit model. This model takes itself the form of a network, that features four main types of nodes: detectors, traffic information centres, traffic control centres and information sockets. We now briefly review their function and relations.

The detectors' purpose is to monitor the status of the network and to detect any traffic event therein. For increased realism, detectors have individually adjustable sensibilities[4], reliabilities, reaction delay and can be positioned anywhere on the network.

Traffic information centres are nodes at which information on detected traffic events is centralized, screened according to parametrizable selection criteria, and then distributed to other traffic information centres, traffic control centres and information sockets.

Information sockets model the various devices that are used to transmit information to network users (radio beacons and dedicated broadcastings, variable message signs, ...). They come in different types, varying according to technology and capacity, but also in the amount of information they can store (memory), time during which information is considered up-to-date (persistence) and ways in which priority conflicts between different messages are handled. They can also be situated anywhere on the network.

Traffic control centres represent instances that decide on traffic management, control and optimization strategies, as opposed to mere information distribution. For instance, they can maintain sets of recommended routes for route guidance applications and fleet management. Recommendations and informations implementing these strategies are also distributed to network users via information sockets.

These four classes of "information network nodes" are themselves linked by communication lines whose reliability and delay can be parametrized. Furthermore, the complete information network configuration (topology and node/link parameters) can be dynamically updated during the design period.

Again, the authors realize that the description of the information network in PACSIM might not capture every possible variant of information processing that can be thought of in the context of advanced driver information systems. However, the present definition already covers a fairly wide ground. It is also easily expandable if new technologies have to be modelled, that cause or result in new information flow patterns.

3.3 Network abstraction

Our previous discussion also recommends the availability of network abstraction mechanisms, in order to reflect the different perceptions of a specific network location by users that are close to it and by users that are further away: close locations are perceived with more disaggregate detail while distant ones are perceived in a more aggregated fashion (where only main districts and major links matter).

[4] That is the type of effect and/or event that they are able to detect (as congestion, accident, unfavourable weather conditions, ...).

According to this view, PACSIM uses a three level hierarchical network representation. The three levels correspond to the *main* network, the *strategic* network and the *detailed* network, from the more aggregate to the more disaggregate. Explicit mappings are defined that assign a node of a disaggregate level to a node of the aggregate level just above, assuring operational coherence to the overall structure. This "multi-level" representation of the network of course plays an important role in the definition of the users' knowledge of the network but also in other parts of the model, as described in the next section.

3.4 Packets

The traffic metaphor used in PACSIM is *based* on behavioural coherence, therefore complying with the above arguments closely. PACSIM indeed considers traffic as composed of the movements of *packets*, which are groups of vehicles moving on the network with a coherent behaviour. They are created at network locations corresponding to origins of transportation demand at a given time, travel through the network and disappear at their destination. The behavioural coherence of the packets is ensured by the requirement that vehicles belonging to the same packet must have in common

1. their capacity to access driver information systems and the traffic knowledge provided through this channel,
2. their mode of transportation,
3. their trip purpose,
4. their destination in the network.

Although the authors realize that these characteristics might not be sufficient to describe behaviourally coherent classes of users, their specification however constitutes a first attempt in this direction.

3.5 The behavioural mechanism

The behavioural mechanism that drives PACSIM is organized along two complementary stages, broadly corresponding to the two phases for behavioural decisions outlined above. The user perception of the network is first established, and a routing decision is then taken within that restricted framework. We now briefly describe these two stages.

The network as perceived by the user (the packet), the *perceived network*, is first defined using the multi-level network representation, according to the following steps.

1. A perceived network is built, that contains a detailed view of the links and nodes in the surroundings of *anchor points*, with the level of detail fading away with distance. These anchor points represent parts of the network that are well known to the user (see Golledge and Stimson (1987)). At present, the origin and destination of the trip are typically chosen as anchor points. This procedure makes full use of the multi-level network structure.

2. Behavioural rules (see Bovy and Stern (1990)) applicable to the packet then modify this restricted network, according to the packet characteristics and the information it has accumulated in past events. This modification can be of two possible natures:

   - the topology of the perceived network may be modified,
   - the relative costs of the perceived network links may be modified.

   In the first case, links can, for example, be removed from the network because they do not belong to the packet's knowledge of the area; links can also be added or reversed as a consequence of dynamic traffic management decisions (as tidal flows) which are communicated to the packets via driver information systems. The modification of costs allows to reflect behavioural preferences (heavy goods vehicle drivers tend to prefer major links, for instance) or again to take available broadcasted information on network congestion into account.

Once the packet's knowledge of the network is established, the behavioural rules are further applied to determine the *route structure* as a sequence of subroutes. These subroutes are finally computed and assigned to the packet. PACSIM actually uses shortest path computation in the modified network for this very last step. It also features a further option to randomly perturb the network cost to represent individual stochastic variations within a single behaviourally coherent class of network users (in a spirit close to that of stochastic assignment, as described in Daganzo and Sheffi (1977) and Sheffi (1985) for example).

We mentioned above that certain behavioural rules are applicable to packets. The set of all these rules constitutes a behavioural theory of route planning, which is used as input parameter by PACSIM. These rules are specified in a formal language that has been specifically designed for the purpose, and which is described elsewhere (see McArthur (1991)). We only stress here that this representation technique has several decisive advantages: formulated in such a formal language, the behavioural theory can be perspicuous, unambiguous, concise and machine readable. We also note that rules expressed in this language cover variations in behaviour potentially influenced by a wide range of parameters as availability, quality, accuracy and timing of user's information, location in the network, trip purpose, transportation mode, time of the day, ...

The inherent behavioural route choice of PACSIM imply that a mechanism is provided for the drivers to memorize some past informations for later use. However, routing information cannot be based on this information only, as has been already observed: in particular, a packet would not be able to start its route in the network because it is just, at this stage, beginning to accumulate information. Some degree of anticipation based on experience is thus necessary. PACSIM provides a mechanism (called the *background network*) to build up such long term dynamic experience of the network, which can be judged admissible in a limited sense (see Dehoux and Toint (1991)). This provides the requested anticipation of traffic effects in the route planning decision process, at the condition that the knowledge of the anticipated effects can be acquired with experience. This long term experience is common to all drivers in the present version of PACSIM, but it might be envisaged to disaggregate it further to better reflect the differences in network experience between different users. At present, PACSIM uses a classical Wardrop equilibrium traffic assignment for computing the background network costs.

As we noted above, it is not clear what behavioural theory will actually prove to be most useful. Hence, the theory that is presently used by PACSIM (see Dehoux *et al.* (1990)) is not aiming at completeness or even correctness: the best that can be hoped for is that something of the *character* of driver response to advanced information systems has been elucidated. One of its purposes is to allow the testing of the behavioural theory representation, particularly with regard to flexibility and efficiency. Better theories emerging from ongoing research projects within the DRIVE program and elsewhere can then be used and tested later without further modification to PACSIM.

3.6 The multimodal aspects

In urban areas, a non-negligible part of the displacements uses public transport. As a consequence, it is reasonable to expect an urban traffic model like PACSIM to take this aspect into account. The method chosen is to include in the model a relatively detailed simulation of the public transport system along with the simulation of private traffic. The same methodology is used, in that the public transport model is dynamic (event-driven) and allows for both multimodal trips (that is trips using both private and public transportation modes) and the provision of advance information systems for users of public transport. The model is of course based on a description of the public transport network, which includes stops, lines, timetables,... as expected.

PACSIM determines the (multi-) modal choice for trips using a behavioural theory for users. In the scenarii tested so far, this theory has always been simplified to the maximization of a user dependent utility function, as is classical in several other techniques (see Ben-Akiva and Lerman (1979) for a general view of discrete choice models, or Bierlaire (1994) for the description of HieLoW, an efficient package for calibrating such models). The utility functions definition of course allows for the representation of "captive" users, that is users for whom only one choice is possible (either they don't have access to a car and therefore have to use public transport, or their origin is not served by any public transportation line). The authors are once more aware that this mechanism may not fully represent the true behaviour of users, and that a more extensive theory is probably desirable. However, the data collection associated with the establishment of such a theory is far from obvious and has not yet been effectively performed in the application cases. It would be extremely easy to include a more elaborate theory within PACSIM if one is available, or, maybe more importantly, if one is interested in measuring the impact of specific changes in user behaviour.

Another important aspect of the multimodal character of PACSIM is that the two transportation modes (cars and busses) are interdependent. In almost all cases (except for dedicated bus lanes), busses and cars share the same road network, and the congestion caused by cars also implies delays for busses. Conversely busses also contribute to link saturation and congestion for private car traffic. This feature has for instance proved useful in the assessment of public transport time tables in the presence of peak-hour congestion.

It must be noted that the packet metaphor had to be adapted for trips using public transport. Indeed, it doesn't make sense anymore to consider packets of vehicles, but one must instead consider packets of users (passengers). In the same manner as vehicle packets are moved within the network, passenger packets are moved from their origin to a public transport stop, where they wait before embarking on a bus (say). Importantly, multimodal trips are explicitly modelled: for instance users can drive from their origin to a parking place and then board the public transportation system, possibly after some waiting time. This feature has allowed the test of park-and-ride strategies with PACSIM. In these tests, a discrete choice utility model was again used to determine the fraction of car users who effectively use the park-and-ride facilities.

3.7 Testing the impact of drivers' information scenarii on congestion

We now describe one particular application of PACSIM, which emphasizes its ability to model the effect of advance incident detection and warning systems. This application was set in the city of Namur, for which PACSIM had been satisfactorily calibrated[5] for a period covering the morning peak hour.

In the application that we describe here, PACSIM was used to test the impact of two classes of drivers' information scenarii on urban congestion in the framework of incident detection and advance warning. The main idea was to simulate, during the morning peak period (7h30 to 9h am), a traffic incident on one of the two important bridges of the city of Namur, crossing the Meuse river and leading to the city centre. The incident occured at 7h55, blocking the bridge until 8h40. The main question was then to compare advance warning strategies using variable message signs (VMS) or specialized radio channels (RDS). The criteria used for the comparison were the congestion levels both on a road close to the incident and on the complete city network.

In a first group of scenarii, we considered the use of one or two VMS situated at strategic sites of the right side of the river. One location (called Chaussée de Marche) carries the traffic coming from the south-east (with important traffic streams coming from Luxembourg) and the other (called Rue de Dave) carries the traffic coming from the south along the right bank of the river. The overall network congestion (total number of vehicles in the modellized network) is shown as a function of time in Figure 1 for the following five scenarii:

1. no incident (and no information),
2. incident without users' information,
3. incident and users' information (1 VMS on Chaussée de Marche),

[5]In particular, the results produced by PACSIM were compared in detail with the application of a traditional stochastic assignment model (see Cornélis (1994)) applied during an unperturbed modelling period.

4. incident and users' information (1 VMS on Rue de Dave),

5. incident and users' information (2 VMS).

One clearly sees that the impact of the tested information scenarii on overall congestion is negligible. We also note that, when the VMS are operated, congestion is higher just after the incident is cleared out. This is explained by the fact that the informed drivers now use longer routes and thus contribute to network congestion for a longer period.

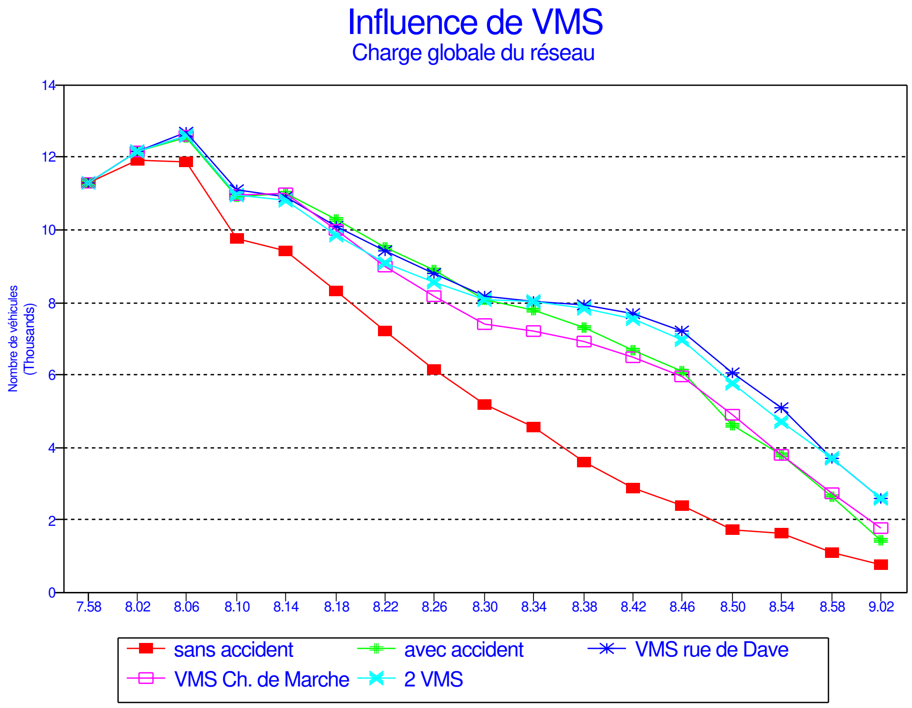

Figure 1: Network congestion for different VMS scenarii

We also present, in Figure 2, the impact of the same five strategies on the number of vehicles on a street (Avenue Bovesse) very near the incident and leading, on the right bank of the river, from the unperturbed bridge to the other. The "Rue de Dave" location gives extremely good results as the informed users can modify their route and take the unperturbed bridge before contributing to the congestion on the studied link. The other location (Chaussée de Marche) has little or no influence on the saturation of the studied link since informed drivers who planned to use the blocked bridge could choose an alternative route which does not include the studied road.

This leads us to not unexpected conclusion that the effects of VMS information strategy are quite local and crucially depend on the localisation of the sign(s).

A second class of scenarii features radio (RDS) information systems, for which we assumed three different levels of market penetration (10%, 20% and 50% of the drivers being equipped of RDS receivers). We also assumed that

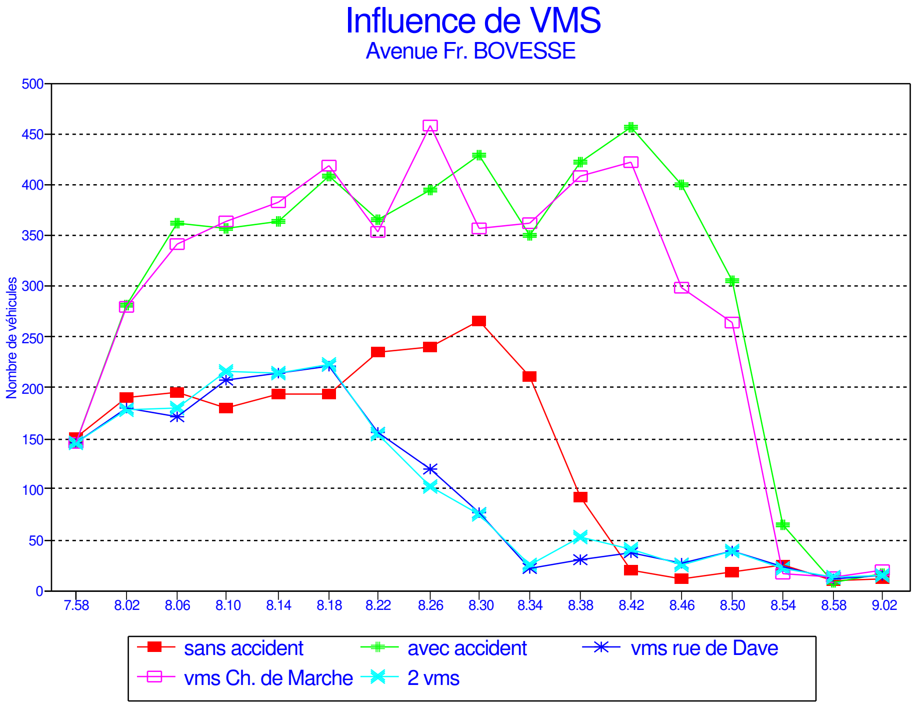

Figure 2: Street congestion for different VMS scenarii

equipped drivers always took the information supplied to them by this channel into account, which amounts to a slight redefinition of the market penetration levels. The congestion levels on the city network and street near the incident are again shown in Figures 3 and 4 respectively, as a function of time and RDS market penetration.

It is interesting to observe that the benefits on global congestion only appear for the highest RDS market penetration level (50%). In the other cases, the number of rerouted users is not large enough to compensate for the local congestion caused by the accident. We see that the RDS information strategy has more global effects, compared to warning using VMS, as users are reached all over the network and not only if they happen to pass a given VMS location.

Of course, the experiments with PACSIM may be (and have been) extended in several other directions. For instance, one could measure the impact of the delay between the incident occurence and the moment where the information is distributed to the users (in the tests described above, a very short delay of 75 seconds was assumed). PACSIM was also used to calculate an optimal location for the VMS on the network (given some specific incident scenarii). Unfortunately, no a posteriori checks could be made because the city effectively didn't implement the system under test in the field. Further work on a posteriori validation thus remains to be done.

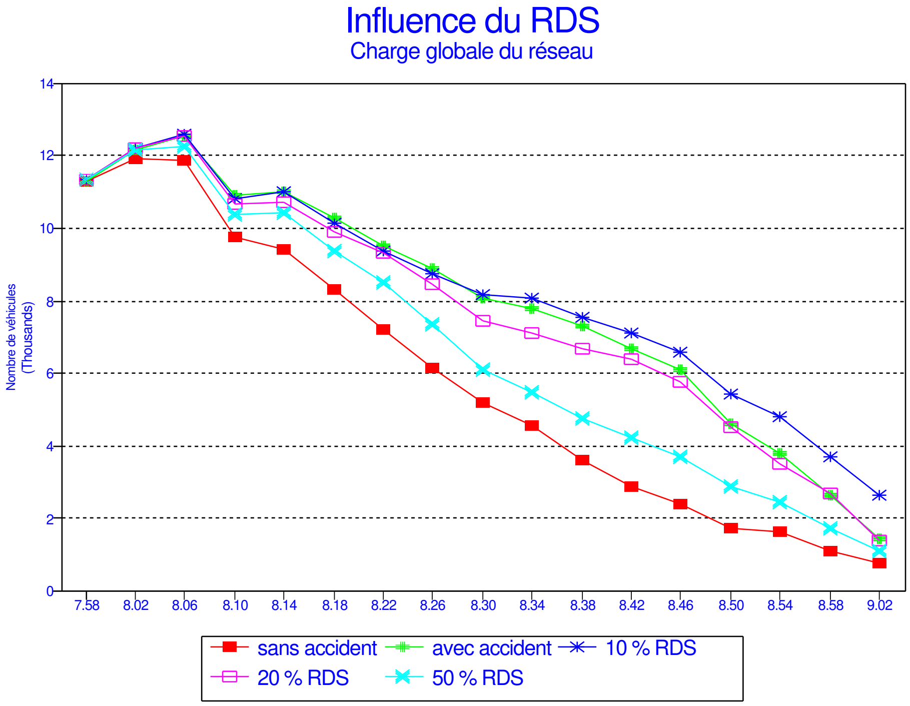

Figure 3: Network congestion for different RDS market penetration levels

3.8 Bus schedule verification

In the second application that we describe here, the multimodal character of PACSIM was used to verify the realism (or lack thereof) of the bus timetables supplied by the bus company. Table 1 shows, for a specific line in the city of Namur, that the supplied timetable only corresponds to a situation with very low congestion level, in which bus traffic is not hindered by that of private cars.

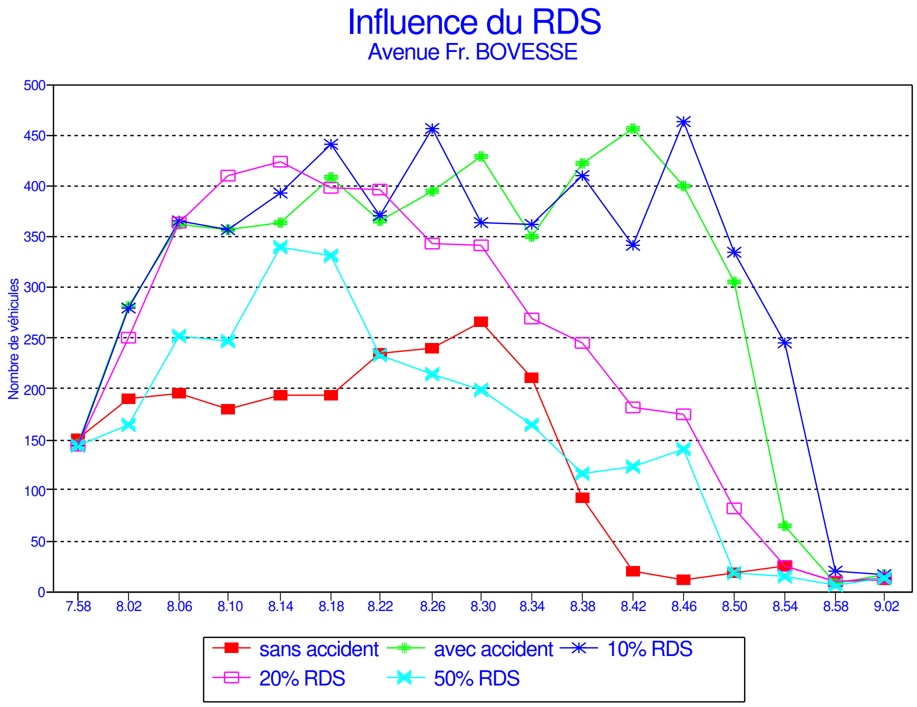

Figure 4: Street congestion for different RDS market penetration levels

STOPS	EMPTY NETWORK	TIMETABLE
Namur Gare routière	7:27:00	7:27
Namur rue de Fer	7:27:52	7:29
Namur rue de l'Ange	7:30:12	7:30
Namur place d'Armes	7:30:54	7:31
Namur boulevard Ad Aquam	7:31:32	7:32
Jambes avenue Materne	7:32:17	7:33
Jambes place de Wallonie	7:34:20	7:35
Jambes station Nord	7:35:05	7:35
Jambes viaduc	7:35:30	7:36
Jambes chaussée de Liège	7:36:10	7:37
Jambes Sarma	7:37:02	7:37
Jambes haute Enhaive	7:37:04	7:38
Jambes l'Atelier	7:39:33	7:39
Jambes Erpent Val	7:39:35	7:40
Erpent chemin de Bossime	7:40:10	7:41
Lives-sur-Meuse village	7:41:27	7:41

Table 1: Modelled vs theoretical (company supplied) arrival times at various stops along line 12

4 Perspectives

Further validation of PACSIM is of course highly desirable, including its use in the context of a real advanced information system. Projects are currently under discussion that would allow this development to take place, notably in Switzerland.

On the modelling front, current efforts in the development of PACSIM aim at coupling the traffic model with a gas pollutant emission model. The detailed level of the simulation provided by PACSIM indeed allows relatively complex emission models to be used. In particular, the number of stops and the engine heating time for a given vehicle can be taken into account. This opens interesting perspectives on the possible use of such a model (and of its behavioural component) for the appraisal of strategies for sustainable mobility.

5 Acknowledgment

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