

## REGULATION OF AN URBAN TRANSPORTATION SYSTEM: TOWARDS A CASE-BASED REASONING APPROACH

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**ABSTRACT:** *This paper presents a classification system based on a case-based reasoning. This approach allowed us to associate a profile of scenario of regulation actions to regulate the disturbances that appear in an urban transportation system.*

*This CBR approach has been implemented in a decision-making system to regulate an urban transportation network. Any planning relies on two classifications processes: hard classification to retrieve a similar to the encountered disturbances and smooth classification when the former fails. Smooth classification is an initial mechanism that could be very useful in case-based reasoning.*

*Displacements of the people are always in the center of the concerns of the persons in charge for the local communities. The quality of transport is an essential element of competitiveness. If the requirements of comfort and safety are the most alarming aspects, it is the reliability and the punctuality of the transport, which generally hold the attention.*

*This work contributes to the advance of the set of themes of the regulation of the traffic of an urban transportation system (bus and tram), particularly the future network of the town of Oran. This problem worries the companies of transport more and more. Especially because users become increasingly demanding, that competition becomes increasingly hard and that the owners have few means of envisaging the appearance of the disturbances which affect the traffic.*

**KEYWORDS:** *Decision-Making System of regulation (DMSR), urban transportation system (UTS), regulator, Case-Based Reasoning (CBR)*

### 1. INTRODUCTION

The goal of this study is to offer a tool of assistance to the operators of the regulation in the centralized unit control (CUC) for the management of the traffic to the level of the inter-stations and correspondences. The principal objective is to elaborate a DMSR, able to solve the problem of management of the disturbances during the course of the vehicles (Bus or tram) as well as the management of the correspondences (Bus/Bus and tram/Bus) under the normal or disturbed conditions. Through that, the quality of service offered to the travelers is improved in their daily displacements. This makes it possible to achieve the major goal, which is the minimization of the latencies of the travelers in the urban transportation system.

It acts then, of the design of a DMSR allowing the regulators:

- to supervise the urban traffic (acquisition of the disturbances),
- to analyze the disturbances by enriching the environment of supervision of the regulator of the network by relevant information on the context

(contextual information) (Pasquier 2002) (Brezzillon 2003),

- to ensure the preclassification of the disturbances, if such is the wish of the regulator,
- to provide alternatives solutions,
- to give an evaluation for each alternative based on relevant criteria,
- to apply the solution adopted by the regulator.

For the realization of the DMSR, the choice of "cognitive engineering" (Milot 2003) approach was essential because of the role of the regulator in the total process of regulation of an urban traffic (Hayat & al., 2005).

The transportation systems being open and distributed, we have recourse to the multi-agent systems (MAS) which make it possible to distribute the tasks between various agents and to make them cooperate for the same goal to know the regulation.

We are interested in this article in the module of the regulation and particularly in the CBR part.

The main objective of the CBR approach is to propose to the regulator in a minimal time, a solution, the most appropriate to deal with the disturbance in progress. This discharge regulator from a heavy tasks particularly familiar disturbances because he spends more than 50% of his time on the radio or over the phone (Bouamrane 2003). Nevertheless, the CBR is useful only when the solution is available in the case base. The case base represents the capitalization of the know-how of the regulator and in the same time a significant apprenticeship system (Hayat & al., 2005).

We present in the section two, the problems related to the field of the regulation, in the section three the advisability of thinking of a CBR. The sections four, five and six will be devoted respectively to the choice of a CBR for the regulation of an urban transportation system, to the development process of a CBR and the CBR model suggested. The section seven is dedicated to the principles of the approach suggested with an example of adaptation. Lastly, we finish with a conclusion synthesizing our proposal.

## 2. PROBLEMS

The problems lie in the fact that the regulation of the traffic is a difficult task, where each decision is taken according to the situation in progress. This is why, the owners of transportation systems try to find solutions increasingly effective. They encounter many difficulties to ensure a stable urban traffic while complying with the rules of use (rules of regulation, safety requirements, and commercial role of the company). In general, the encountered difficulties are due to the bad conditions of circulation (for example: delay generated on the various lines of the network), with the lacks of personnel and material (for example: absence of a driver or breakdown of a vehicle) and with the uninsured correspondences (between the vehicles of the same mode of transport or different modes of transport).

For better ensuring the regulation in their CUC, the appearance of the Automatic Vehicle Monitoring (AVM) helped the regulators much. The AVM allow the follow-up in real time of the exploitation of an UTS. The AVM treat very large quantities of information but the regulators do not manage to deal with this great number of information for the decision-making, in the event of disturbances. The decision-making requires to take into account the most important information. A Computerized decision-making system (DMS) is necessary in order to help the regulators to make relevant decisions for the regulation of the traffic, in the event of possible disturbances. The DMS for the regulation or DMSR is interactive: it must be able to inform the regulator about precise points by providing targeted and relevant information. The regulators to which addresses the DMSR melt their actions on their knowledge making in the field of the regulation as on information which is

provided to them on the context (Brezillon 2003) of the disturbances. Thus two incidents, in addition identical, are not treated same manner in peak hour as in off-peak hour. The period of the day being a determining factor for the choice of the procedure of regulation. In off-peak hour, the regulator can consider less constraining strategies in material and human resources. The elements of the context of the disturbance such as the period of the day, which play a part in the choice of the strategies, are numerous in the case of the management of disturbance on the urban transportation network.

## 3. REFLEXION APPROPRIATENESS'S ON THE CBR

To locate the case-based reasoning, it is necessary to see the work of (Minsky, 1975) (Schank, 1982) (Schank and Riesback, 1989) and Winston (Winston, 1988) on the paradigm of the reasoning and the memory. The directions given by this first work still largely inspire the most recent evolutions of the CBR.

This artificial reasoning has for goal to propose solutions to a problem belonging to a class of problems usually encountered by the decision maker. It rests on a basis of case where are recorded the situations already met and to a measure of similarity between the situations.

Various observations carried out (Bouamrane, 2003) (RCATUO, 2004) (TaM, 2005) on the level of the regulating CUC showed that the latter adopted strategies distinct from regulation and that the action of regulation selected was different from a period to another, from where interest of a hierarchisation of the cases as well as the exploitation of an indexing per behavioral situation based on the concept of event-driven chronicle. Indeed, it is the arrival of a disturbance at a given moment, for a given situation, which determines the choice of the regulator. The concept of know-how is prevalent, from where need for taking into account the set of the solutions suggested by the set of the regulators. At first sight, that seems heavy to manage, but the installation of adequate structures of filtering makes it possible to limit the number of cases per disturbance.

The choice of a CBR is justified by the important surge of information; this type of system reasoning by analogy can discharge the regulators from the set of the cases of familiar disturbances. This kind of technique with already proved reliable (Fuchs & al., 1995) (Jaczynsky et Trousse, 1997) (Leake, 1996). But few of these techniques are intended for the regulation of transportation systems. Indeed, only work of (Pasquier, 2002) uses a CBR exploiting the contextual graphs for the regulation of a subway line of Paris managed by the RATP<sup>1</sup>.

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<sup>1</sup> RATP: Autonomous Control of Transport of Paris

Moreover, among the existing tools of decision-making or diagnosis, none offers the possibility of integrating knowledge test. However, the experience is part of the used knowledge and it is a decisive factor in the decision of the operators. This has been demonstrated in studies conducted on the pilot sites, where the training of operators foresees putting them into position by simulation (Fuchs 1997). As such, the proposed DMS integrates the experience of the regulator through a case base operated by a CBR module.

Consequently, it is proposed below the appropriateness of the choice of this approach (Bouamrane, 2006).

1. the regulator is generally an old conductive of which the know-how accumulated during years enables him to anticipate the disturbances and to know in the majority of the cases, which actions of regulation to undertake,
2. all the expertise of the regulator is based on lived experiments,
3. various solutions can exist for the same disturbance, that depends on the regulator in command,
4. the regulator can be confronted with new disturbances, but that relates to mainly the bimodal network (installation of a tram),
5. files on the disturbances and their corresponding regulation exist in the form of entry of charge, but are used only to a statistical aim,
6. entries of charge can be exploited to build a database of cases. Moreover, within the framework of our work, an expert system (KS) is used to enrich the base by case as soon as a new case is proposed and validated by the regulator.

The regulators have a mainly technical initial training. After several years on the ground as a general-purpose supervisor (conductor, agent of operation...), the future regulator follows a formation in the field of regulation traffic and the management of incident on the lines of transportation system (Bus or tram). During this formation, the future regulators learn the procedures.

This initial formation provides to the regulators the necessary elements to the regulation and the management of the incidents (Fourage, 2002). The latter is supplemented by the experience gained during their service. Each new disturbance is an occasion to improve.

Another important period of experience sharing between regulators takes place after the incident, and especially at the time of the changing (Pasquier, 2002).

The network of Oran obtaining soon a line of tram, the future regulators doesn't have any experience on the way of controlling this new bimodal network. Through a CBR module, it is proposed to them an approach for the regulation having capacities of training in order to capitalize the experiment of the regulators. This being realized with an aim of facilitating the transmission of the know-how of certain regulators tested or foreigner

expert intervening with the other emergent ones in the trade and for better re-using acquired knowledge.

For this purpose, in this study, the technique of CBR is adopted for a bimodal network, which does not show the same characteristics as a subway line (guided system), with an interaction between two means of transport and division of the ways (Bus and tram). For that, a system of indexing per behavioral situation is proposed. Lastly, let us note that the CBR within the framework DMSR makes it possible to capitalize the set of the solutions suggested by the regulator, which represents a considerable training. The regulator being the final decision maker, it can accept or refuse the proposals made by this module (Bouamrane, 2004).

In the case of the regulation of a Bus, several types of behavior of the regulators with respect to the disturbances are observed. For the same disturbance, and according to the experiment of the regulator, different solutions can be obtained (Mariné & al., 1988). The CBR does not give a report on these differences. For that, it was introduced the concept of index to be able to characterize in an individual way each solution.

#### 4. DEVELOPMENT PROCESS AND FORMULATION OF A CBR SYSTEM FOR AN UTS

The construction of a CBR system passes by five (5) distinct stages: 1) Case Construction, 2) Research, 3) The adaptation, 4) The Revision or Checking, 5) Maintenance or Training

In our study, the construction of the cases is carried out manually or by the means of the KS, which enrich the casebase, by solutions validated by the regulator. We will note, that for the revision of the cases, we use an external mechanism of evaluation that is based on a multicriterion approach (Roy, 1985) to establish a classification allowing to retain the best placed case source.

The casebase represents the central knowledge base of the CBR and is noted *Base-de-Cas*. Each element of *Base-de-Cas* is called case source. A case source is noted by  $cas-source=(source, Sol(source))$  where source is called disturbance source. The figure (1) shows identification process of the disturbance source inspired of the square of analogy (Bouamrane & al., 2006) (Chouraqui, 1986).

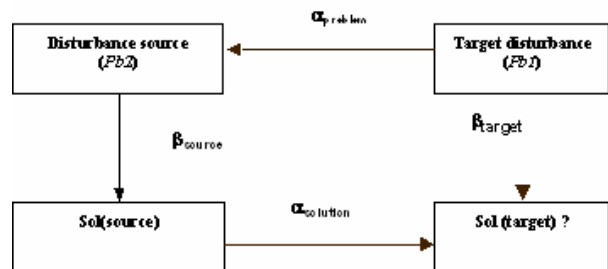


Figure 1. Identification process of disturbance source

with :

$\alpha_{\text{problem}}$  : Partial order with which the target disturbance and the disturbance source are compared

$\beta_{\text{source}}$  : Indexing of the set of the source solutions by exploiting the evaluations of the disturbances  $\text{Idx}(\text{Source})$

$\alpha_{\text{solution}}$  : Extraction of the best solution (following the indexing),

$\beta_{\text{target}}$  : Cost with which the target solution was obtained (not considered in this study).

Being given a disturbance source, the CBR system has as task to exploit the casebase to solve the target disturbance. This reasoning is carried out in two phases: research and the adaptation.

1. the research aims to seek in the casebase such as the disturbance source is similar to the target disturbance. Is called reminded case.
2. the adaptation has as a task to build a solution of the disturbance source.

## 5. THE CBR PROPOSED MODEL

The CBR Model suggested exploits an indexing based on a behavioural situation. It is about a set of indices describing an evolution in time of state contrary to the indexing based on an instantaneous situation, which represents a set of indices defining a state in a particular moment. The behavioural aspect often makes it possible to better describe a situation and represents for many problems an essential component of the description of the situation. The taking into account of a set of behaviours in the indexing was exploited in several applications based on the Case-based reasoning; we quote work of (Rougegrez, 1994) (Nakhaeizadeh, 1994) (Bull, 1997) (Fuchs & al., 1995) (Ram, 1993). Its exploitation for the regulation of an UTS (assistance to the supervision of process), represents, a first attempt.

### 5.1. Presentation of the indexing by behavioral situation

To develop the indexing by behavioral situation, it is necessary to define the concept "behavioral situation" (Jaczynski, 1997).

The indexing by behavioral situation supposes the observation of a process which moves in time. It is often the case in problems of diagnosis, forecast or order.

In this kind of problems, a process represents a physical process or a human activity proceeding in an environment. The process has a set of characteristic variables of its state. These variables take values at various moments, using a unit of time suitable for the observation of the process called chronicle. The situation term was defined by Kolodner (Kolodner, 1993) as a "set of indices, relevant and discriminating characteristics of a case or current problem". Consequently, a behavioral situation is the set of the indices, which represents in particular the relevant behaviors of certain variables of the process and their temporal relations. A behavioral

situation must be seen like a temporal extension of an instantaneous situation, and thus does not exclude that certain indices represent instantaneous values.

### 5.2. Interest of the indexing by behavioral situation

The indexing by behavioral situation must be used for problems which show the two following characteristics (Jaczynski *et al.*, 1997): the process is relevant for the activity of resolution of problems; and/or the temporal relations between the values of the various variables of a process are relevant. In the case of the regulation of an UTS that results in (off-peak hour, it is not possible for lack of knowledge, to-peak hour, changing hour); abstract or model the various behaviors and their relations to describe an instantaneous situation. For the same situation, two regulators can propose different actions of regulation. These characteristics are found in many existing CBR systems, which tackle on the one hand problems of forecast and on the other hand problems of control and supervision of process. These are the same characteristics that are found in the CBR system intended for the supervision of an UTS in order to ensure its regulation.

## 6. THE PRINCIPLES OF THE SUGGESTED APPROACH

### 6.1. Representation of the similarity

While referring to the figure (1), it can be stated that  $\text{Sol}(\text{target})$  is obtained by adaptation of the reminded case "case-source" of the target disturbance. *case-source* is not necessarily adaptable to the target disturbance : the adaptation can fail and not give a solution. Consequently, two approaches of the classification (recollection) can be distinguished: the first is based on research in the casebase of the case *case-source* nearest to target; the second consists in guaranteeing that reminded case is adaptable to the target disturbance. The recollection presented in this work is situated in the first approach. It uses an explicit representation of the similarity.

### 6.2. Recollection and classification

Let us consider pb1 as being the new acquired disturbance (target) and pb2, the disturbance present in the casebase (source), figure (1). In the proposed DMSR system, the CBR module is organized in the form of a database (records). The disturbances which arrive are compared using a partial order " $<$ ". In this case, if  $\text{pb1} < \text{pb2}$ , we can say that the disturbance pb1 is more specific than pb2 (i.e. the values of the parameters of pb1 are included in the intervals of those of pb2).

Each recorded disturbance becomes a solution source for the casebase. This stage, we associate to him an index  $\text{indx}(\text{source})$  such as  $\text{indx}(\text{source}) \geq \text{source}$ : an index is a generalization of a disturbance. The indices are organized in a *Hidx* hierarchy for the order  $<$ . A source

solution is added to the hierarchy by considering a threshold from which it can be retained in the hierarchy. This threshold is established on the basis of following parameter: particularly duration of the disturbance, period of the day and localization of the disturbance.

The search of a disturbance recorded using *Hidx* is based on two processes of classification (Lieber and Napoli, 1997). A Hard classification where only the strict equality of the two structures of case is taken in consideration. And in the event of failure of the latter, i.e. when there is not identical disturbance source treated, smooth classification is activated. This stage, the CBR module seeks a function of approximate modification *fml* such as:

$$\text{Source} \leq \text{indx}(\text{source}) \cong \text{fml}(\text{indx}(\text{source})) \quad (1)$$

Where  $\cong$  is read "similar to" and means "equal to near modification".

This function of modification is based on the comparison of a certain number of parameters by respecting various thresholds. The parameters and their thresholds are presented in table (1).

Parameters	Delay	Localization	Period	Means of transport
thresholds	$\pm 2$ min	$\pm$ either a preceding stop, or a following stop except if it is the terminus	even period (time of the disturbance)	even means of transport

Table 1. Parameters and thresholds of *fml*

Research in CBR model seeks a similar treatment to the target disturbance. It establishes consequently how they are similar. *source* is similar to *target* in the case of a strict equality or if the relation (1) between source and target is checked. The strict equality or the relation (1) is called "ways of similarity".

The calculation of the similarity in the case of the regulation of an UTS is based on six data, the four suggested in table (1), added two parameters concerning the calculation of the distances compared to the next stop and the next terminus.

The adaptation (Lieber and Napoli, 1997) then consists in generalizing the solution *Sol(source)* of source in a solution *Sol(Indx(source))* of *Indx(source)* and to specialize this general solution in a solution *Sol(target)* of target, which we can note by the following diagram, figure (2):

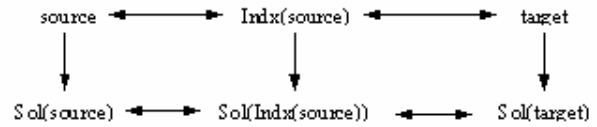


Figure 2. Generalization of the source solution

### 6.3. Modeling of the CBR

The general algorithm of the CBR was inspired from the work of (Lieber and Napoli, 1997). This algorithm deals with only the stages of recollection and adaptation, i.e. without the stage of training. A function recollection (research) is considered, it takes in entry (input) a target disturbance and turns over a couple (case-source, *sim(source, target)*) where case source are an element of the casebase and *sim(source, target)* is a way of similarity of case-source to target. In the event of failure of the recollection and *sim(source, target)* will be equal respectively to failure  $\{\emptyset\}$ .

The adaptation is regarded as an adaptation function which starting from a target disturbance, of a case-source and a way of similarity *sim(source, target)* associates a solution *Sol(target)* of target. Contrary to the recollection, the adaptation should never turn over an empty set  $\{\emptyset\}$ .

The following algorithm presents the organization of the functions recollection and adaptation for the proposed CBR.

#### Algorithm CBR(target)

**Input :** a target disturbance

**Output :** a solution *Sol(target)* of the target disturbance or  $\emptyset$

1. Research a case *cas-source* = (source, *Sol(source)*)  $\in$  casebase and a way of similarity *sim(source, target)* from source to target :
2. If *cas-source* =  $\emptyset$  then **return**  $\emptyset$
3. Adapt *cas-source* to target with *sim(source, target)* :  
 $\text{Sol(cible)} \leftarrow \text{Adapt}(\text{target}, \text{cas-source}, \text{sim}(\text{source}, \text{target}))$
4. **return** *Sol(target)*

### 6.4. Example of adaptation

As indicated in introduction, we exploit a multi-agent architecture like (Balbo 2000) (Gruer & al., 2001) (Laichour 2002) (Fayech 2003) supporting the various modules of regulation. We refer to this architecture in this example. Either, a disturbance assigning the bus vehicle N° V7 of line 11 at 10:12 am (off-peak period). Creation by the agent DIAGNOSIS of an agent RAPC (agent having in charge the CBR module) starts an operation of recollection (research). This last operation, by considering a smooth classification and by exploiting the thresholds suggested in table (1) identifies three source disturbances (case-source) recorded beforehand. What corresponds to the hierarchy of index (three

different solutions represent possibly three different behaviors resolving a disturbance arriving during the same time). Each one of its solutions has its own evaluations. Table (2) represents the three solutions with the evaluation of the three essential criteria retained for multicriterion research.

	Solution 1	Solution 2	Solution 3
Regularity Criterion	1	0,8	0,2
Punctuality Criterion	0,8	0,5	0,3
Correspondences	0,6	0,5	0,5

Table 2. Representation of the solutions found at the time of the research with evaluation of the criteria<sup>2</sup>

The first, second and third solutions correspond respectively to a “half-turn on line”, a “half-turn on line with exchange of drivers and travelers” and a “regulation on line”. From there, a multicriterion method of outclassing is adopted in order to determine the best-classified solution.

First of all, we must arrange the criteria in three categories of weight: extremely, means and weak. Then, comes the moment from the evaluation of each solution (indx) compared to each criterion.

Thus, all the allowed notes have the same base of notation, and there is not to normalize the results, nor to take account of the weights during the aggregation of the results. Relatively to this notation, we build a matrix of evaluation, table (3) with in line the solutions obtained by the means of the indexing and in columns the criteria. In the suggested example, let us regard the criteria of “regularity” and “correspondences” as criteria with strong weight. The criterion of “punctuality” will have an average weight.

	Regularity criterion	Correspondences criterion	Punctuality criterion
Solution	2.5	2.5	6.5
Solution	5	7.5	5
Solution	7.5	7.5	8

Table 3. Matrix of the weights of evaluation

We use the multicriterion approach Electra III (Roy, 85), a calculation of the difference of the notes d between two solutions for an unspecified criterion is carried out. We can calculate this difference for all the couples of solutions, relative with all the criteria. We also fixes for all the criteria of the thresholds preferably strong (noted p) and preferably weak (noted q).

A threshold of veto is also considered; such as if the difference in notes is in absolute value higher than this

<sup>2</sup> The various criteria are evaluated between 0 and 1 what corresponds to the interval 0% to 100%.

threshold, we exclude the action, which behaves badly on this criterion. Then, an index of credibility is granted to the assumption “Solution 1 outclasses Solution 2 for the criterion considered”, according to the level preferably defined by the thresholds preferably.

Then, we fix various thresholds on the indices of agreement and discordance, in order to determine preferably relations (strong or weak), and indifference between the solutions. A graph can be deduced, and thereafter a classification of the solutions.

By considering our example with the thresholds according to, table (4):

	Threshold of Weak preference q	Threshold of strong preference	Threshold of veto v
Regularity criterion	0.2	0.8	0.5
Punctuality criterion	0.8	0.3	0.5
Correspondences criterion	0.3	0.2	0.5

Table 4. Implementation of the data with the thresholds

We then obtains the graph of the figure (3) where solution 2 dominates solution 1 and 3; and solution 3 dominates solution 1 from where the classification of the solutions.

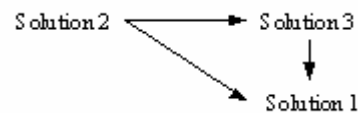


Figure 3. Graph of predominance of the various solutions (classification)

Consequently, it is the solution 2 which will be adapted to the target disturbance in our example. At the same time, the set of the criteria (Bouamrane & al., 2006) are revalued with specific information of the disturbance within an update in the casebase.

Despite the fact that the multicriterion approach can offer the most appropriate solution, based on assessments in the case of CBR, it is for the regulator in position to validate or not the decision.

## 7. CONCLUSION

This article presented a CBR approach suggested for the regulation of the disturbances of an urban transportation system. This approach is exploited to capitalize the set of the solutions suggested by the regulators, which represents a considerable training for the DMRS. The regulator being the final decision maker, it can accept or refuse the proposals solutions made by this model. Moreover, one indexing of the cases by behavioral

situation is proposed. This representation translates mainly the difference in behavior for the regulation of a Bus network. Indeed, for the same disturbance and according to the experiment of the regulator of the different solutions can be obtained. The CBR does not give a report on these differences. For that, the concept of index was introduced to be able to characterize in an individual way each solution. With regard to the regulation of the tram, the actions of regulation are standardized a little taking into account the characteristic of the network (guided). Nevertheless, that does not prevent from keeping the solutions suggested by the various regulators of the tram. Moreover, for the revision phase of the CBR system we exploited a multicriterion approach instead of the traditional approaches very often considered.

The development of the model in general and the CBR in particular has been done in the spirit of integration of knowledge and the user in the same cognitive environment to take advantage of their complementarity's and thus, ensure a better interactivity.

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