# Multi-agent Modelling for a Regulation Support System of Public Transport

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Abstract: The increasing cost of private transport and the rising pollution of the environment pose serious problems in society, economy and environment. The public transport has become a major challenge of collective and daily life. However, to encourage people to use a public transport system, the offered service have to be with good quality. This paper gives effective solutions to improve the quality of public transport service provided to users. In this paper, we present a Regulation Support System of Public Transport (RSSPT), based on Multi-agents approach that allows supervising and regulating a multimodal public transport. Its purpose is to adjust the vehicle schedules where several disturbances come simultaneously. The adjustment is based on actual traffic conditions. It covers the major criteria that have to be optimized in a traffic regulation: punctuality, regularity and correspondence.

## 1 INTRODUCTION

The regulation of public transport is a complex task, in which decisions are taken according to the current state of the road network. The network operators encounter many difficulties to maintain a consistent traffic and forward planning: theoretical time table, and respect the use rules (safety rules, business rules, commercial rules, etc.). The disturbances must be identified and corrected following the punctuality criteria, regularity and correspondence. These different criteria define the service quality of the passenger in terms of waiting time at station and the trip time. To insure these criteria the system must respect the theoretical times of vehicle at station for punctuality, respect the time interval between vehicles of the same line for regularity and respect the waiting time passenger at transfer station for correspondence.

Hence, the regulation is the mechanism that leads to effective action decision after collecting the necessary information and optimizing the service quality of passenger in terms of punctuality, regularity and correspondence. It must also deal with several kinds of disturbances at the same time (vehicle breakdowns, absence of drivers, blocked route, etc.) and cover the multi-modality network.

Our objective is to build Regulation Support System of Public Transport for multimodal traffic that is able to supervise and regulate the traffic. Our model takes into account the major criteria that have to be optimized in a traffic regulation: punctuality, regularity, and correspondence (Karim, B., Bonte, T., Sevaux, M., Tahon, C., 2005). It also deals with many disturbances at the same times by distributed decision. The plan of this paper is as follows: section 2 introduces the related works and there limits. In the section 3 we justify the choice of multi-agent approach in the modelling of our regulation support system. Section 4 describes the functional model and the multi-agents architecture. The section 5 presents an example of simulation and result. The last section gives a conclusion and future works.

## 2 RELATED WORKS

The approaches can be classified into two families:

### 2.1 Mathematical Approaches

Salah Zidi (Salah, Z., 2007) in his thesis


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proposes a technique based on a Support Vector Machine (SVM) and ant colony algorithms. However the regulation action acts only on vehicles passages schedules without considering other objectives such as correspondence and regularity. The offered solution is a reconfiguration of new schedules or routes according to the new traffic conditions.

Sofiene Kachroudi (Sofiene, K., 2010) proposes a regulating approach for both private and public modes on wide urban network. This approach uses an optimization method for particle swarms. It's a simple meta-heuristic implementation. But it doesn't address the problems of correspondence and punctuality.

R. Hartani (Hartani, 95) establishes linear mathematical models characterizing the vehicle movement between two successive stations of a public transport line in a high density. This method effectively treats punctuality. However, there is no direct link between the calculated values and their impact on the modification of vehicles kinematic values (e.g. position, velocity, acceleration and jerk: third derived from of position). In addition, the update of the vehicles time table is not done in real time and the correspondence is not taken into consideration.

Mohamed Mahmoud Ould Sidi (Mohamed, M., 2006) proposes in his thesis a resolution method that takes adequate measures regulations for each incident. The method used is based on evolutionary algorithms with the theory of sub-assemblies and fuzzy integrals. Nevertheless, his method does not address punctuality, regularity, and feasibility.

## 2.2 Approaches based on SMA

### 2.2.1 Regulation of Traffic Lights

(Sofiane, H., Neïla, B., 2010) (Neila, B., Lotito, P., 2005) (Neïla B., Flavien, B., Suzanne, P., Mohamed, T., 2011) The objective of these approaches is to act on the traffic lights durations to regulate traffic of private cars and public transport mainly buses. They only address the traffic lights regulation in a normal state in order to adjust the regularity criteria. But, the correspondence and the punctuality are not treated. Also, they don't deem a real cause of the disturbance and don't address the multi-modality network.

### 2.2.2 Regulation using Evolutionary Approaches

Flavien Balbo (Flavien, B., Scema, G., 2000) propose a multi-agent representation based on "Property-based Coordination Principle" (PbC). The objective of this approach is to solve three recurring problems in the design of solutions related to knowledge, space-time dimension and the real environment dynamics. The tests show the importance of multi-agent representation. However the three main criteria (punctuality, regularity and correspondence) are not explicitly covered in this approach.

Fayech (Fayech, 2003), presents the regulation as a reallocation of schedules and itineraries for vehicles affected by the disturbance. This approach requires Hamiltonian paths to ensure the feasibility of the allocated itineraries. However, this technique doesn't deal with traffic regularity. Furthermore, the decision to change or allocate new itineraries can cause problems for the correspondence.

Bouamrane (Karim, B., Bonte, T., Sevaux, M., Tahon, C., 2005) presents a regulation model that details the cognitive activities in the regulation process. The decision is integrated in an interactive environment, but it is based only on punctuality.

Laichour (Laichour, 2002), proposes to regulate only the correspondence problem by using a limited number of actions.

Soulhi (Soulhi, 2000) proposes a fuzzy model technique. His model is based on the regulator experience. This technique provides only synthetic results and deals only with the punctuality issue.

## 2.3 Discussion

Most of the existing works have limits for the public transport regulation:

- They don't take into account perfectly the major criteria that have to be optimized in a public transport regulation: punctuality, regularity and correspondence.
- The majority of works don't address the public multimodal transport (bus, metro and tram)
- The majority of works take account only the information related to passengers like waiting time in station, frequency of coming passenger, destination of passenger, etc. It is difficult to collect and manipulate this information.
- They can't handle multiple disturbances simultaneously.
- They don't detect on time the disturbance.
- They don't ensure a follow up of the regulation action impact in order to update the information system on real-time and develop its expertise in regulation.

Hence, our goal is to implement a Regulation Support System of Public Transport (RSSPT) that overcomes theses limits. For this, we rely on a multi-agent approach. This orientation is explained in the next section.

# 3 MULTI-AGENTS APROACH AND REGULATION SUPPORT SYSTEM

In this section we describe the regulation public transport domain characteristics and we show how each of these characteristics can be handled by a multi-agent approach. The regulation public transport is:

- **Distributed:** The geographical distribution of information over the network for vehicles and stations requires distributed agents. Each agent has its own information in order to reflect the real current state of the public transport network. For example, when vehicles breakdown or there are delays or accidents.
- **Dynamic:** it is the daily change of information concerning the management of public transport. The system must then use agents able to continually modify their states and automatically adapt to dynamic changes in the environment. For example, a vehicle agent can move forward, slow down, accelerate and negotiate its passage with other agents like stations.
- **Open:** The state of public transport networks changes continuously. E.g. the appearance of incidents or the number of vehicles becomes large. Hence the system must manage agents who can enter and exit freely. For example, add a new regulator agent when a disturbance appears and add a large number of vehicle agents to simulate congestion situation.
- **Heterogeneous:** The actors of Regulator Support System are varied. The use of a multi-agent approach allows modeling agents with different behaviors and different granularities. For example, vehicle, station, regulator, etc.
- **Complex:** this domain requires entities with complex nature. These entities can reason and communicate via messages to solve problem. For example, each regulator can manage and makes a decision, and each vehicle can communicate with station to give some information like passage time.

Therefore, multi-agents system sweets well the public transport network domain. Hence our modelling is based on agents able to communicate, cooperate and negotiate to detect and resolve disturbances.

# 4 SUPPORT REGULATION SYSTEM MODELLING

## 4.1 Objective

Our goal is to provide a regulation support system of public transport (RSSPT). This system is based on Multi-agents approach. It is designed to detect and regulate disturbance of public transport by taking into consideration the major criteria for traffic regulation: punctuality, regularity, and correspondence. Furthermore, this modelling should simultaneously treat many disturbances and consider the multimodal aspect of the system (bus, metro, and tram) as well as the type of vehicles (passenger, school, commercial, etc.). The mode of transport is important to treat the feasibility; also the type of vehicle is useful to define the significance of the criteria (punctuality, regularity or correspondence) in the evaluation disturbance.

Our system is based on the system presented by Karim Bouamrane, (Karim, B., Bonte, T., Sevaux, M., Tahon, C., 2005). It is subdivided into three modules: the disturbance acquisition, the regulation and the evaluation module.

## 4.2 The Functional Model

The following figure describes the different phases in the decision-making process of the regulation (see figure 1).

In the first phase, the system supervises the network. It collects information from the operating support system of the public transport network to locate vehicles. After that, it detects disturbances and evaluates its impact on network activity by computing utility function based on punctuality, regularity and correspondence. This function is inspired by the work of Catholijn who presents a prototype system for negotiation about cars (Catholijn, Jonker, Treur, 2001).

In the regulation phase, the system analyzes detected disturbances by defining the type of risk (risk of a vehicle train and / or the risk of a gap). It produces diagnostic and the current state of the network. According to the diagnostic the regulator establishes solutions following an optimization of the utility function and takes the adequate decision for example to increase or to decrease the number of vehicle provided for part of the network, to accelerate or decelerate vehicle, etc.

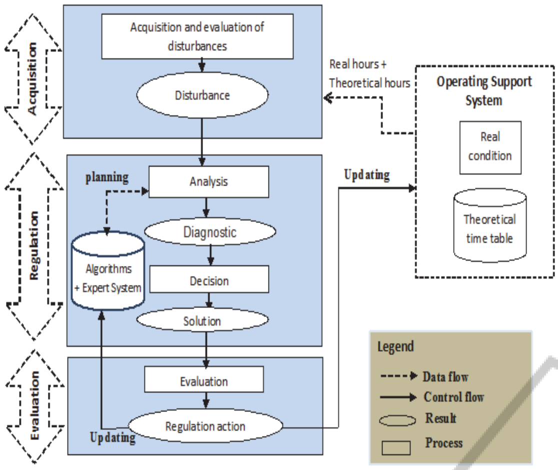


Figure 1: The functional model of the RSSPT.

Finally, there is the evaluation. The model chooses the regulation action according to its feasibility and controls it in public transport network.

## 4.3 Multi-agent Architecture

The different agents of our architecture are described in figure 2.

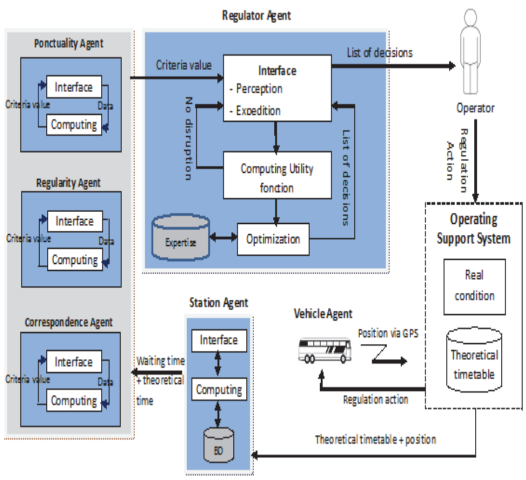


Figure 2: Multi-agent Architecture of the RSSPT.

Our architecture is based on multi-agent approach where agents include domain knowledge. Their interactions are based on the environment state. To achieve our RSSPT we design agents that store data from a theoretical time table and reflect the current state of the network (**station** and **vehicle**) as well as agents that calculate and evaluate disturbance and solution for the three criteria: **punctuality**, **regularity** and **correspondence**.

### 4.3.1 Agent Modelling

- **Station Agent:** is related to one or more lines. Each agent must memorize all theoretical times and real times of vehicles passage. It calculates continuously the waiting time of each coming vehicle $V_{R\_v}$. It is equal to:

$$V_{R\_v} = T_C - T_{T\_v} \quad (1)$$

With $T_C$ is the Current time and $T_{T\_v}$ is the theoretical time of coming vehicle. After that, it provides the necessary information to agent punctuality, regularity and correspondence so they calculate their criteria value.

- **Vehicle Agent:** is characterized by mode (bus, metro or tram), position, speed, capacity, number of passengers, line which affected, mission (academic, commercial or passenger), driver, remaining work time, etc. When a vehicle passes, it provides to the station a passage time, number of passengers descended and number of passengers mounted. Also, it gives continuously to the operating support system via GPS its position. This information is stored to enrich the knowledge base of the system. Also, each agent vehicle is related to each criteria agent who use these information to calculate its criteria value.
- **Punctuality Agent:** calculates its criteria value $V_p$ as follows:

$$V_p = (T_C + \Delta_{Rt}) - T_{T\_v} \quad (2)$$

With $\Delta_{Rt}$ is the remaining time needed to the real time of vehicle passage. This remaining time must take into account the traffic state and the mode of transportation.

- **Regularity Agent:** calculates its criteria value $V_r$ as follows:

$$V_r = V_p - T_{R\_v\_behind} \quad (3)$$

The $T_{R\_v\_behind}$ is the real time of behind vehicle passage (see figure 3).
When $V_r$ value is less than vehicle frequency, it means that there is a risk of a vehicle train. Otherwise we deduce that there is a risk of a gap.

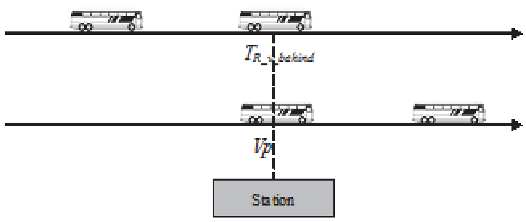


Figure 3: Calculation of the regularity criteria value.

- **Correspondence Agent:** calculates its criteria value $V_c$. It is equal to:

$$V_c = \sum_{i=1}^{n} f_i\,(\Delta_{i\_v\_c}) \tag{4}$$

Here $f_i$ represents the waiting time factor of $i$th corresponding vehicle. This factor indicates the importance weight of the corresponding vehicles in the calculation of the regulation solution. It is necessary that $\sum f_i = 1$. And $\Delta_{i\_v\_c}$ represents waiting time of $i$th corresponding vehicle. It is equal to:

$$\Delta_{i\_v\_c} = V_p - T_{i\_v\_c} \tag{5}$$

With $T_{i\_v\_c}$ represents the real time of the $i$th corresponding vehicle passage to the transfer station.

- **Regulator Agent:** Each vehicle has regulator agent that continuously receives the criteria values calculated by the agent's punctuality, regularity and correspondence. Then the regulator calculates the utility function according to three criteria (punctuality, regularity and correspondence).

$$U=\sum_{i\in O}(W_i.V_i) \quad with\ O=\{p,r,v\} \tag{6}$$

Here the weights $W_i$ are relative to the importance of the different criteria. E.g. punctuality for school bus is more important than the passenger bus, against keeping good correspondence is more interesting for passenger bus than school bus. The weights values are between 0 and 1 and It is necessary that $\sum_{i\in O} W_i=1$ with $O=\{p,r,v\}$.

### 4.3.2 Dynamic Modelling

We describe dynamic view of our model by using the sequence diagram (see figure 4).

Each station knows the position station from the operating support system and calculates the waiting time from each coming vehicle and sent it to criteria agent. So, each criteria agent calculates its criteria value and sent it to the regulator agent. After that, the regulator agent calculates the utility function. If the value of this function falls into a critical values space, the regulator starts the regulation phase. In this step the regulator use its expertise to optimize the utility function and produce a hierarchical list of feasible decision. This list is inspired from the work of Z. Salah (Salah, Z., 2007). After that it sent this decision list to the operator. The operator maximizes the solution satisfaction degree and respects the decision feasibility. The value of this function must be as minimal as possible. It is the value of the theoretical utility function.

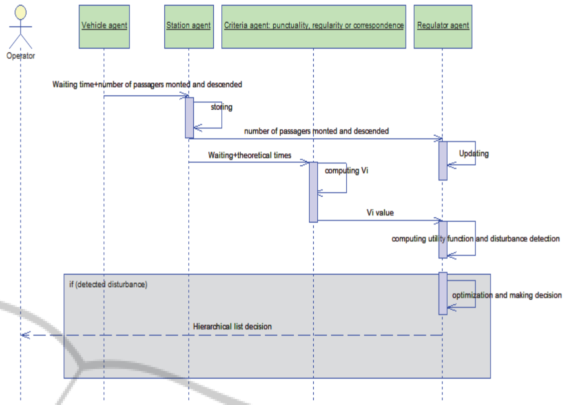


Figure 4: Sequence diagram of the RSSPT.

At the end, the operator chooses the appropriate regulation action decision from this list. After that, the system updates its knowledge base, and updates the information of operating support system. We note that each vehicle has a regulator that operates independently of other regulators.

A unique characteristic of this model is that the same agents and data are used to ensure the three phases of our RSSPT: acquisition, regulation and evaluation. This makes the model simpler and solves the problem of data duplication.

In addition this architecture detects the disturbance on time and ensures self-organization among the different agents to achieve a collective goal. Furthermore, the regulation can deal with many disturbances at the same time and the solution is taken into account a real time.

## 5 SIMULATION AND RESULT

We applied this work to scenario based on a real transportation system existing in Abu Dhabi. We used an algorithm with a line 008 which has frequency bus 20 minutes (regularity). A disruption, due to a traffic accident between two cars, slows down bus. The delay of the disrupted bus at its arrival to the Bateen station is estimated 7 minutes: We estimate that there are 4 minutes for the coming bus to arrive at station ($\Delta_{Rt=}$4) and 3 minutes that the coming bus not comes yet at 10h: 33min. The disrupted bus has two correspondences lines 009 and 010. We assume that there is no disturbance on the behind bus. To calculate the correspondence criteria, we assume that all corresponding bus have the same importance in the transfer station ($f_1$=0.5 and $f_2$=0.5).

According to the theoretical time table presented in the following table (see table 1), each criteria agent calculates its criteria value as following: $V_p$=7, $V_r$=27 and $V_c$=15. The regulator agent calculates also the utility function: U=16.86. We want to find regulation that minimizes this value. Note that the optimal value is equal to theoretical value=8.58.

Table 1: Times of bus passage at Bateen station.

| Line | Theoretical time at station | Real time at station | Frequency |
|---|---|---|---|
| 008 | 10h: 30min | 10h: 37min | 20 |
| 009 | 10h: 23min | 10h: 23min | 20 |
| 010 | 10h: 25min | 10h: 25min | 20 |

After analysis of the situation, the system recommends that the better action regulation is a deviation: change the road of the disruption bus without skip stations. In this case the disrupted bus comes 3 minutes earlier and the utility function value becomes equal to 10.23 with $V_p$=4, $V_r$=24 and $V_c$=3. We deduce that the utility function is simple to use and a good way to optimize the regulation action.

## 6 CONCLUSION AND FUTURE WORKS

In this paper, we presented a Regulation Support System of Public Transport (RSSPT) based on a multi-agent approach. Unlike other works, our model takes into account the punctuality, regularity and correspondence. These criteria are detected and regulated at the same time when several disturbances appear simultaneously. Moreover, this RSSPT deals with multimodal traffic of public transport

The objective of this research is to improve the passenger quality service of public transport. In our approach, regulation of public transport is distributed and obtained thanks to communication, collaboration and negotiation between heterogeneous agents. Firstly, we explained shown that existing approaches of support system regulation present several limits. Secondly, we have presented how we used multi-agents approach in our modelling. Thirdly, we described our multi-agent strategy that computes utility function on witch making decision is based. This function is based on the real condition of traffic situation and takes into account criteria: punctuality, regularity and correspondence.

The first experimentation shows that our RSSPT can sort the different feasible regulation actions according to the utility function value. The implementation is in progress using a multi-agents platform JADE. A deeper validation will be done using with a real value of the traffic network.

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