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DEVELOPMENT OF A MULTI-CRITERIA DESTRUCTION MANAGEMENT MODEL FOR A BETTER URBAN TRANSPORT SYSTEM QUALITY

The object of the research is the urban transport quality. The problem to be solved in the course of the study to optimize current planning systems while reducing human impact on managing daily disruptions that affect urban transport quality and citizen well-being. This will allow all buses to run on time and all users to travel in good conditions. This study aims to address the most critical problems of the growing demand for public transportation, the inability to meet these demands, and the approved ineffectiveness of existing planning.

In the course of the research, it is proposed to apply a model for managing daily disturbances that used a developed algorithm based on four major aspects. These aspects include admitting all actors into the system, collecting real-time data, processing data to manage their exploitation and destruction as quickly as possible, and even achieving an ideal operational strategy to handle potential disruptions to the system.

Authors' proposal for achieving this goal involves two types of hardware and software architectures, taking into consideration the use of modern technological innovations and their potential application. While ensuring a good flow of information, which contributes greatly to the proper functioning of the network and even to the proper management of disturbances in real-time. To validate this work, it is possible to simulate an application of this model on an existing situation of a transport line in the city of Constantine (Algeria), already studied in a previous study to see the evolution of the situation in terms of quality reflected by the journey time.

As a result of the research, it is shown that positive feedback and improvement were observed after the first simulation of the application. This result only encourages the application of this proposed approach, which could ensure a better quality of service offered to the users. In the future, the application of this proposed approach could be the revolution of the field of urban transport in Algeria, which is the pillar of the viability, productivity, and efficiency of a city and the well-being of the citizens.

Keywords: *disturbance management, service quality, customer satisfaction, urban transit, urban bus operations.*

1. Introduction

The service quality offered to bus transportation systems users is a critical element of competitiveness for the operators who operate it. However, the effective management of disruptions is a vital aspect regarding traffic regulation that must ensure the control arising during the operation of the transport network [1]. With the increasing demand for public transport, the inability to meet these demands, and the approved inefficiency of existing planning, several research projects aim to optimize planning systems including good management of disruptions to avoid the consequences of this inefficiency translated as non-quality offered to users. Now, as current bus planning is carried out by humans influenced by the constraints of daily life, it becomes necessary to automate the system to manage the daily disturbances encountered by people traveling by bus [2–4].

Disruptions are often related to the peculiarities of each bus line, the fluctuation of demand related to peak hours, occasional situations (holiday departures, cultural events, weather conditions, road accidents, congestion and traffic jams, road works, social movements such as strikes and demonstrations, differences in the number of times passengers climb and descend, the driver's driving style, a mechanical incident on the bus, etc.). For this, access to real-time data is necessary and becomes required to know the exact state of the line and to decide which exploitation should be applied on time according to obtained cases [5, 6]. Moreover, to be able to accurately measure travel times in real-time, which is the most important information in terms of the efficiency of a transport system, it is necessary to use models that take into account all possible disturbances [7].

In this work, it is tried to propose an approach that will be used to collect and process the data provided in real-time to better exploit the bus transport system. Let's took as an application example the city of Constantine (Algeria), which has experienced a massive rural exodus and a continued population growth [8]. This rapid growth has caused

critical mobility and accessibility problems [9]. So, how can it better manage these problems to meet user needs?

To achieve this aim, developed model implemented a variety of measurement methods, algorithms to manage disruptions, and an information delivery system, including a goal to replicate client satisfaction. In this way, the appearance of this mode of transport can be improved, the number of passengers increased, and this mode of transport will become more convenient, comfortable, accessible and understandable for all, and this guarantees quality mobility for the user, the objective of our present work.

2. Materials and Methods

The purpose of this contribution is that all buses run on time and that all users can wait and travel in good conditions. As a result, the best use of the line is based on a reliable data collection system with the implementation and updating of all system components while ensuring a good flow of information, contribute greatly to the smooth operation of the network and even the proper management of disruptions in real time.

To achieve this objective, an approach is proposed to properly manage the disturbances; therefore, it is possible to drawn up the following action plan:

– plan the data to be collected which allows to provide a kind of cartography for the assessment of the situation, then it is interested in the way of collecting these data on the one hand and ensuring a circulation of information between all the actors of the system, on the other hand;

– ensure real-time communication between all concerned not only to intervene on the disturbance in real time but also to keep them informed of the overall situation;

– in addition, to complete this project, it is necessary to provide two types of hardware and software architectures;

– a multi-criteria destruction management model is developed;

– then the application of this model is simulated on a disturbance with real data by proposing an action plan estimating the efficiency of each action before executing the solution as a final step.
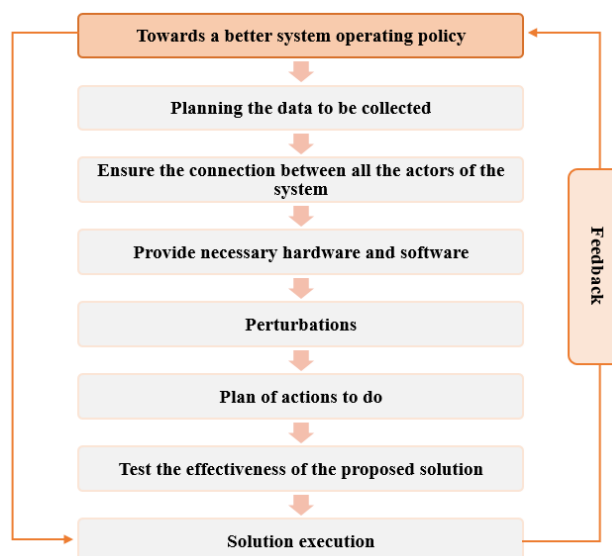
This methodology is explained in Fig. 1.

Fig. 1. Work process

2.1. Process of collecting, processing, and displaying data. Since better operation relies on a reliable data collection system from all its components while ensuring a good flow of information between them, to avoid any destruction consequences, this has a significant impact on the proper functioning of the network and the line.

This approach is based on four main elements: introducing all the actors related to the system, collecting real-time data, processing the data for efficient operation, and finally operating the optimal strategy [10]. In Fig. 2, let's present the plan of the various data to be collected from all the actors of the system connected to each other to ensure the flow of information in real time.

To realize this work, it is possible to set up a relational diagram to link all the actors concerned: the user, the buses as rolling stock and personnel, and the agents, all managed by the admin (Fig. 3). Let's mention that during the structure of this project, other actors are necessarily added, namely: stations, lines, customer and agent returns, and disruptions and their solutions.
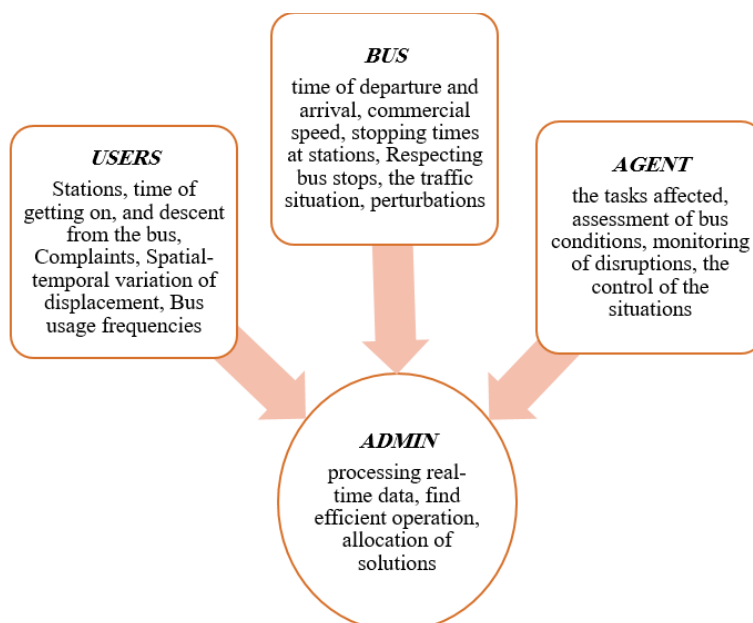

Fig. 2. Plan of the various data collected
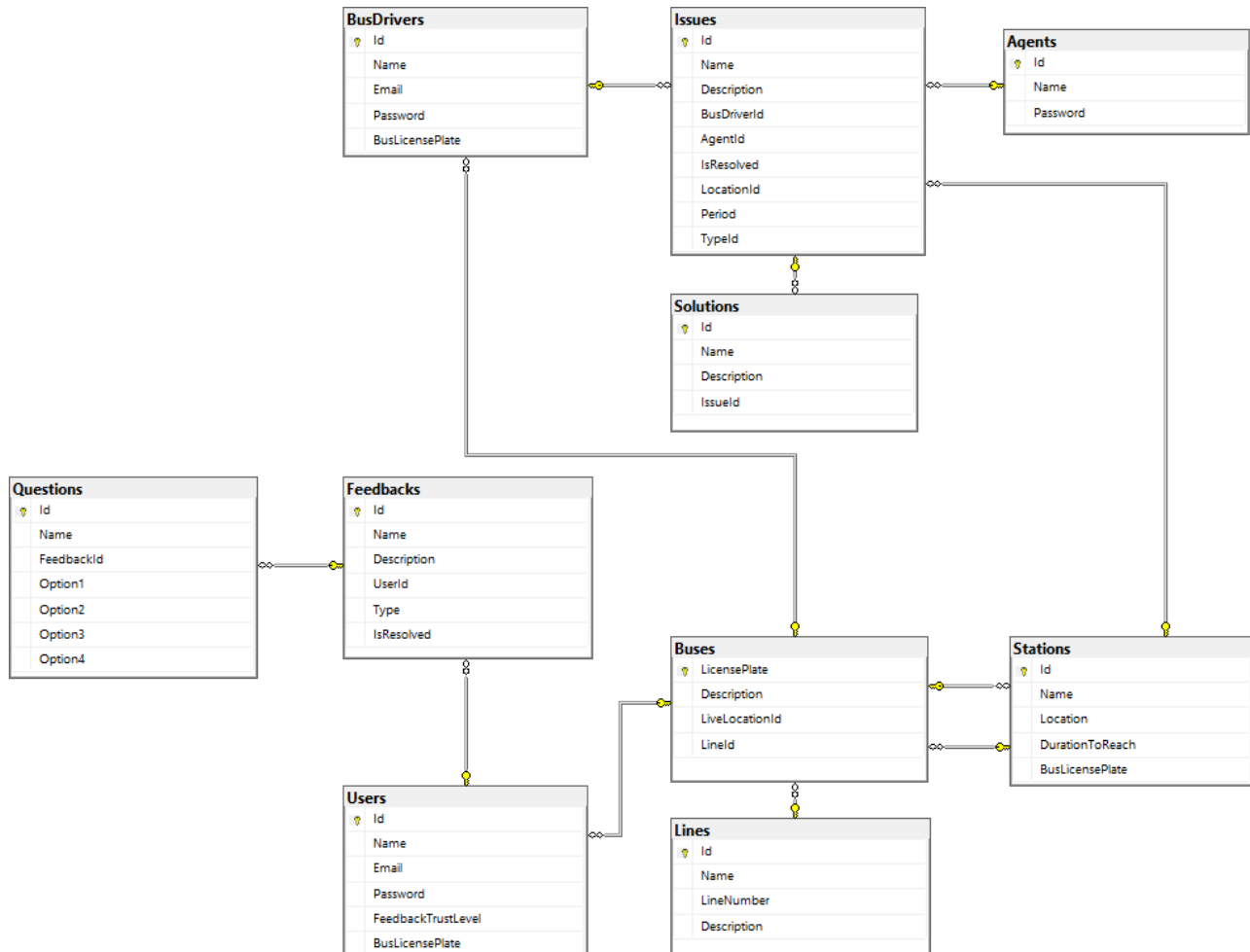
Fig. 3. Project relational diagram

In order to execute this approach, two architectures will be made available: hardware and software (Fig. 4), arranged into three components: data recovery, data processing, and display. The plan was to use existing tools to recover, process, and carry out solutions on time and within budget. Therefore, the most viable tool for recovering data from users, agents, and bus drivers is the 3G or 4G using ordinary smartphones. Without a smartphone, the user can still use a smart card to do the work, while the bus is fitted with a card reader and a GPS SIM box to collect real-time bus location information. This data will be recovered at the admin application level using a desktop equipped with a server, where all the data is transformed into C# language by simplifying their use with the Dot Net Framework and Entity Framework Core [11]. Microsoft SQL Server is used to store, manipulate and recover data stored in a relational database [11], and it produces tasks, orders, and information to be displayed.

Fig. 4. Project hardware and software architecture

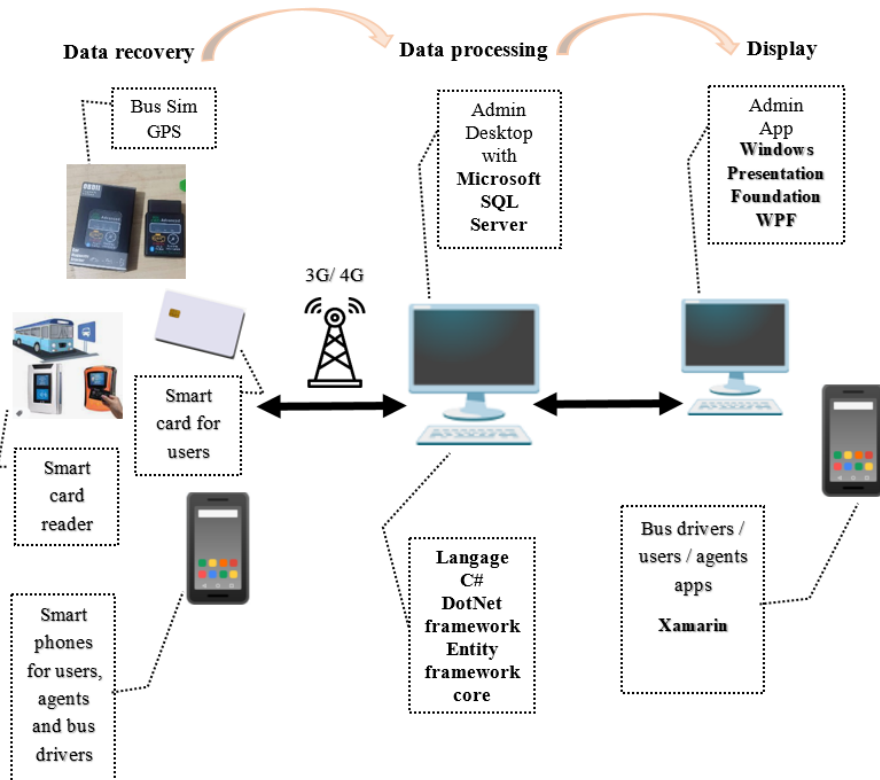Xamarin, which is a part of the open-source .NET platform is the most utilized tool for android development. It is the responsible for the display of the user application and agent on their smartphones in this last step, where both software and human contact are involved. It is free and there are no fees or license fees, including for commercial use [12]. For the display of the admin application and BUS, the choice was for the use of Windows Presentation Foundation (WPF), which provides a complete set of application development features including controls, data link, layout, 2D and 3D graphics, animation, styles, templates, documents, media, text and typography [13].

2.2. Development of the multi-criteria destruction management model. This model targeted two main problem axes: demand fluctuations by period and traffic disturbances. Therefore, the multi-criteria entered data guided to propose a combination of classification, codification, and treatment approaches already conducted on this topic for better managing any system destructions, our model process is shown in the following figure (Fig. 5).
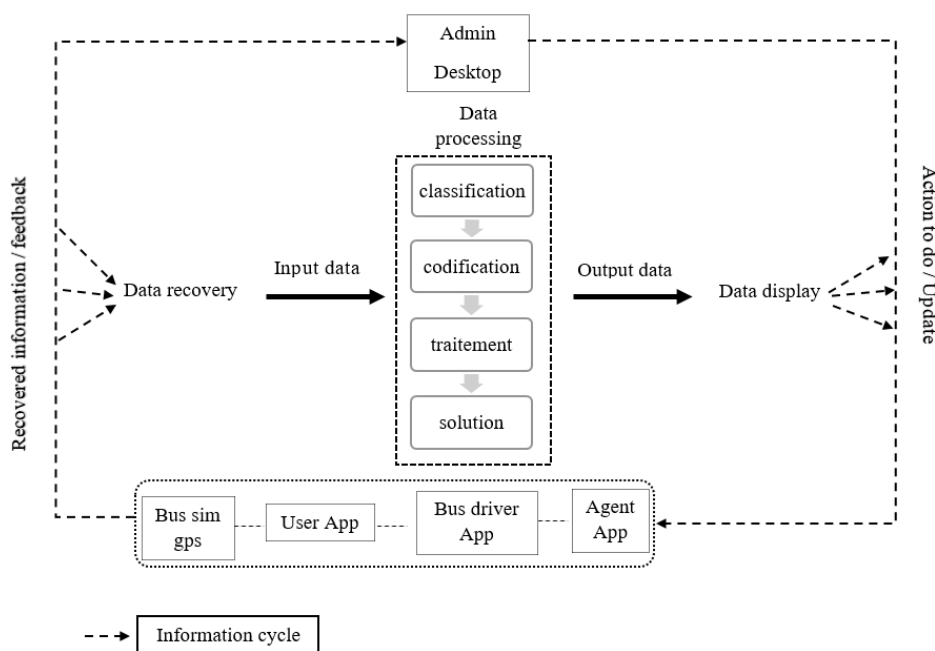

Fig. 5. Multi-criteria destruction management model

The main important phase of this approach is the data processing phase divided into classification, coding, and treatment of the recovered data in order to execute the optimal solution in the form of an action plan to be carried out, this will be illustrated as follows.

2.2.1. Classification of the entered data. To achieve better management of the demand fluctuations, three major services are proposed: a service in off-peak hours, a service in peak hours, and an occasional service [14]. These periods are different from one line to another; its description related to the lines demand is possible using the data gathered from users' applications and payment smart cards.

– *Off-peak hours service:* operational during weekends and hours of low demand.

– *Peak hours service:* is operational during weekdays and hours of high demand.

– *Occasional service:* is operational during occasional events such as public and religious holidays, official visits, holidays, etc.

Furthermore, it is possible to categorize the causes of disruptions to improve management and assign the most effective solutions, namely:

– *Class 1:* human disturbance includes any disturbance caused by the driver, agent or user. In the form of absence, delay or urgency.

– *Class 2:* disturbance due to rolling stock, includes the various failures and anomalies caused by rolling stock.

– *Class 3:* disturbance due to traffic conditions, any delay or advance caused by traffic conditions, traffic lights, congestion, accidents, etc.

– *Class 4:* disturbance due to infrastructure conditions, any disturbance caused by problems or work on the road and stations.

It is also possible to note that the gravity of the situation relative to lost time is also of significant importance when allocating the solution.

– *Gravity type 1:* where time lost is less than 10 minutes;

– *Gravity Type 2:* where time lost is between 10 and 20 minutes;

– *Gravity Type 3:* where time lost is greater than 20 minutes.

In addition, the location of the disturbances stations plays an important role in the decision, this importance reflected in the stopping time of buses according to the number of users who get on and off the bus.

There are 4 station sections [7]:

– *Short section:* where stops are in low demand and bus stopping time is low;

– *Medium section:* where demand at stops varies with time, and bus stopping time is not static;

– *Long section:* where stops are often requested, and bus stopping time is long.

– *Terminal section:* where the bus reaches its destination.

Moreover, two types of large and small buses are available depending on their positions [2]:

– large bus on route;

– large bus available;

– small bus on route;

– small bus available.

2.2.2. Codification of the entered data. The main goal was to build a decision-support structure to handle situations [1].

For that, Table 1 presents the codification of the variables, which describe the situations, for a better contribution to decision support.

Coding of variables

Variable	Notation	Codification
Type of service	$X1$	– off-peak hours service: $X1=0$; – peak hours service: $X1=1$; – occasional service: $X1=2$
Disturbance classification	$X2$	– human disturbance: $X2=0$; – disturbance due to rolling stock: $X2=1$; – disturbance due to traffic conditions: $X2=2$; – disturbance due to infrastructure conditions: $X2=3$
Gravity of Disruption	$X3$	– gravity type 1: $X3<10$, $X3=0$; – gravity type 2: $10<X3<20$, $X3=1$; – gravity type 3: $X3>20$, $X3=2$
Station Section	$X4$	– short section: $X4=0$; – medium section: $X4=1$; – long section: $X4=2$; – terminus: $X4=3$
Bus type	$X5$	– large bus on route: $X5=0$; – large bus available: $X5=1$; – small bus on route: $X5=2$; – small bus available: $X5=3$
Solution	Y	Algo 1, Algo 2, …. Algo X

2.2.3. Data treatment and solution display. Based on the classification of the input code data, a solution algorithm is proposed for each situation as follows:

$$Y=(X1, X2, X3, X4, X5). \tag{1}$$

Let's note, here that the proposed solution algorithms are inspired by feedback from situations already experienced, while the objective is to associate with each given situation the corresponding optimal solution. The objective of the solution is to bring the initial journey time displayed to the customer closer to the one affected by the destruction, the equation used to test the effectiveness of the proposed solution is as follows:

$$\Delta_t=TP_{initial}/TP_{after}\cdot100, \tag{2}$$

where $TP_{Initial}$ is the time displayed to the client before the disruption; TP_{after} is the time displayed to the client after the assignment of the solution; Δ_t is the efficiency ratio.

The more Δ_t converts to 100 %, the more efficient the solution is. It is opted for 90 % as the accepted percentage of the solution's efficiency.

To ensure the model's effectiveness, let's test it by simulated an example on a real dataset, as follows.

3. Result and Discussion

Our simulation will be on one of the lines already studied in a previous study to see the evolution of the situation in terms of quality reflected by the journey time, which is the most representative indicator of this situation [15]. Our study line 'new city Ali Mendjeli/Djebel el Wahch' contains two main types of buses: large and small buses, with a filling capacity, varying between 25 and 100 users, it presents disturbances that need to be resolved. The bus concerned our study is a 100V8, it was the return bus from Djebel el Wahch to the new city Ali Mendjeli at 12:00, which marks the longest travel time on the study day, a user who wants to go from the FOUBOR that is one of the stations of the line to the last station in the new city Ali Mendjeli, wants to pass its request via its phone application at 12:12,

the result displayed is 13:50 pm as a reach hour. The bus crossed by congestion at the four stations DROJ, SNTV, DAKSI, SMK, according to the feedback of the drivers of this line; this congestion appears regularly every weekday. The reach time on the user application is updated following time lost due to this congestion; it became 14:07 pm.

This case is, therefore, relative to the following data:
– $X1$: 12:00 pm is a peak hour service in this line.
– $X2$: the disturbance crossed is congestion due to traffic conditions.
– $X3$: time lost during congestion is 17 minutes 29 seconds.
– $X4$: the stations are located in a long section.
– $X5$: the bus studied 100V8 is a large bus on route.

This increase in journey time, determined by the following:

$$TP=Tpr+(Ts+Tc)+Tsr, \tag{3}$$

where TP – the journey time; Tpr – time travelled; Ts – station downtime; Tc – time lost during congestion; Tsr – time lost due to road signs.

In this case, the most flexible variable to manage when increasing congestion time to protect journey time is the reduction of station downtime. The parking time consists of boarding times and disembarking passengers, it is clear that the user takes more time when boarding the bus. This time is estimated at 70 % of the total parking time due to the payment procedures, for this, algorithm 1 proposes:
– for the BUS1, the study case bus: service descent only for stops following the stops affected by congestion;
– for the following bus BUS2: descent service only on the short and medium section of stops before congested stops, and minimization of stopping time when necessary at long section stops and after congested stops;
– assignment of an available BUS3 bus, for the recovery of users from the stops of the short and medium sections left by BUS2.

The application algorithm of this approach in this case is Fig. 6.

The execution of this situation is as shown in Fig. 7.

After applying the model required, the driver supposed to receive a message with the proposed solution, this will affect a decrease in travel time declared to the customer during the application by updating the display on its application. The evolution of the journey time of this situation is shown in Fig. 8.

It is observed that the journey time after a first application of the solution begins to diverge from the time affected by congestion, and converges to the initial journey time station after station. This remains in our opinion to be improved, counting on the database collected by our technology to have an estimate and in particular an action plan for disturbances in order to avoid their consequence.

However, despite the positive results obtained from this simulation, it is faced with numerous limits of applicability, starting with the nature of the culture of citizens, where a majority of the population is not accustomed to the use of these technologies, as well as the diversity of operators and the lack of qualification of drivers. For this, to ensure the proper application of this approach, it is necessary to implement citizen awareness and compulsory professional training for current bus drivers and strict recruitment conditions for future drivers.

```
InitialTime //first journey time
displayed to users

nextStationTime // stations downtime
from the actual station

nextStationShortSectionTime, // short
section stations downtime from the
actual station

congestionTime // time lost due to the
congestion

int X1,

int X2,

int X3,

int X4,

int X5)

{

delta;

solutionTime; // journey time after
applying the solution

RightNowTime; // the increase journey
time due to the congestion

var msg = new Message();

// Calculate RightNowTime

RightNowTime = initialTime +
congestionTime;

if ((X1 == 1) && (X2 == 2) && (X3
== 1) && (X4 == 2) && (X5 == 0))

{

// Calculate solution time

solutionTime = RightNowTime -
(nextStationTime * 0.7) -
nextStationShortSectionTime;
```

```
// Calculate delta

delta = initialTime.TotalSeconds /
solutionTime.TotalSeconds;

// Determine message title based on
delta

if (delta >= 0.9)

{

msg.Title = ("descend");

}

else

{

msg.Title = ("normal");

}

//Log message and solution time to the
server

Await_serverClient.Child("Message")
PostAsync(msg);

await_serverClient.Child("SolutionTi
e").PostAsync(solutionTime);

}

else

{

//Ask admin for a better solution

msg.Title = "Please provie appropriate
solution";

await_serverClient.Child("Message").
ostAsync(msg);

}
```

Fig. 6. Approach algorithm

```
https://myfirsttest-6ce11.firebaseio.com/
│
▼── Message
    ▼── -NSSsWbNzlvxXhlYox-m
        ├── Id: 0
        └── Title: "Descend only service"
▼── SolutionTime
    └── -NSSsWl1PUb96iA7vHgc: '01:49:01.1000000'
```
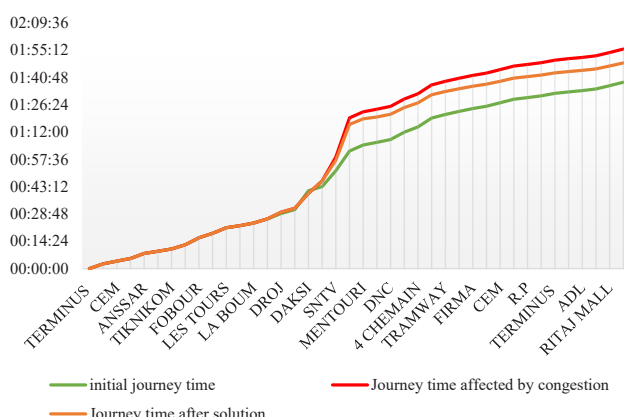
Fig. 7. Algorithm execution

Fig. 8. Journey time evolution

4. Conclusions

In this study, it is possible to obtain a positive result after an initial simulation of the application on real field data,

with an efficiency ratio estimated at 90 %. This enables to gain approximately 7 minutes and move closer to the initial time that displayed to the client before the disruption. This result only continues to encourage the application of this proposed approach which could ensure a better quality of service offered to the customer not only by offering it the necessary information before and during its trip, but also to enable it to contribute directly to the improvement of the system by their complaints and proposals transmitted by its application.

The circulation of information between the actors of the system was the aim of this technology, it facilitates strongly the reflection on the disturbances treated by the administration and attributed to the agents and the bus drivers.

This approach will also ensure a rich database by keeping each information introduced into the system; this database will facilitate the monitoring of the situation as well as the estimation of the regulation of the proposed schedules particularly according to the variety of demand according to the periods.

Certainly, this system contains limitations, citing the prevailing culture, the difficulty of application because of the variety of operators, unqualified bus drivers and degraded rolling stock as well as the nature of the Algerian mentality that is not accustomed to this kind of technology.

Despite its so-called limitations, the application of this proposed policy could be the revolution of the field of urban transport in Algeria, which is the pillar of the viability, productivity and efficiency of a city and the well-being of the citizen. Therefore, an attempt to apply this approach will be proposed at the level of the research team of the national transportation ministry.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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Data availability

The manuscript has no associated data.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

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