

# Multi-criteria analysis of urban public transport problems: the city of Fes as a Case

Imane MOUFAD, Fouad JAWAB

**Abstract**— The object of this article consists in identifying the problems of the sector of urban public transport in Fes, and analyzing these problems in order to come up with a reliable and fine vision on the state of the latter. We developed these problems by introducing, in the first place, the importance of the sector of urban public transport, sound evolution and the means of transport which compose it. Secondly, we propose a model of governance allowing to unite all the concerned actors and to define the role of each by using the "Pieuvre" diagram. And then, we lead an investigation to involve all stakeholders in the identification of problems from which the Fassi citizens suffer concerning public transportation across the development of semi-directive discussions. Finally, we perform a prioritization of problems in order to find the most critical ones and so to define those to solve at first by basing on multi-criteria analysis methods.

**Index Terms**— Modelling, Identification, Graph "Pieuvre", Multi criteria analysis, interviews, investigation

## 1 INTRODUCTION

Through this article, we are trying to highlight the problems that the sector of urban public transport of the city of Fez suffers from. We tackled the subject by landing, on the one hand, the sector of the urban public transport. The latter makes it, besides its importance in the economic and social development of the city; it lived several changes which trace the evolution of its governance of the public monopoly in the Public Private Partnership. In the second part, we introduced a model of governance allowing to gather the set of the concerned actors and to define the role of each by using the diagram "Pieuvre". Such tool allows a graphic representation of the correlations of a system with its environment. In the third part, we are identifying the above-mentioned problems, by using a participative approach to stakeholders based on semi-directive interviews to have some reliability on the state of the sector. And finally, based on the complexity of the studied sector, we undertake a multi criteria analysis to discover the most critical problems and so to define those to solve first and foremost.

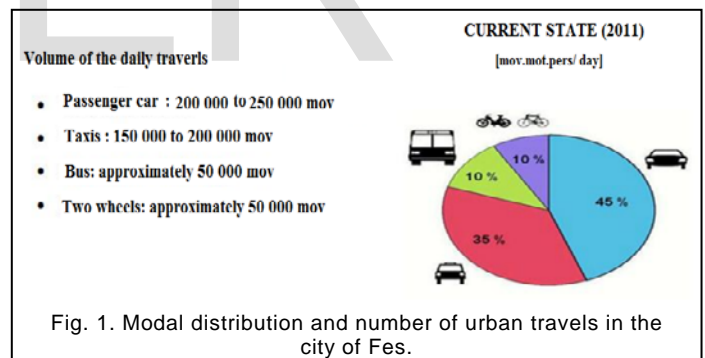
## 2 URBAN PUBLIC TRANSPORT IN THE CITY OF FEZ

### 2.1 Importance & value of the urban transport sector

In the city of Fez, urban transport is a real urban planning tool. It is a tool in the service of production and consumption that define the daily life of all the citizens. Indeed, it constitutes a necessary means, notably for peripheries, with access to services and basic equipment such as schools, universities, health centers, administrative centers, etc. The

- Imane MOUFAD, Industrial Energy and Sustainable Development Laboratory, School of Technology, Fez - Morocco; imane.moufad@gmail.com.
- Fouad JAWAB, Laboratory of International Management and Logistics Decision Technology & LPE2D, School of Technology, Fez - Morocco; jawabf@gmail.com

modal sharing out of displacements points out a weak usage of the collective transport by bus in the city which does not exceed the ratio of 15 Journeys by citizen per year [3]. For example, the same ratio is ~35 Day / year / person in Marrakech and of ~ 45 Day / year /person in Casablanca. Because of uninterrupted urban staggering and of evolution of living standard, there is an important margin of growth of displacements motorized in general. The Figure 1 shows the modal split and the number of urban transport in the city of Fez.



### 2.2 The means of urban public transport in the city of Fez.

#### 1) The taxis

Like the Moroccan cities, Fez has two types of taxis: "small taxi" and "large taxi":

Small taxis also called taxi 2nd category or red taxis circulates within the urban perimeter with a fleet of about 2,700 vehicles<sup>1</sup> in 2014. It is the ideal means of transport in the city and there is a room for the maximum 3 people. The price of the ride is 1.40 MAD (boarding) + 0.20 MAD by 100 meters. Night rate: + 50% of the price [27].

Then, Large taxis also called white taxis or taxis 1st category constitute an area of vital and strategic activity in the

<sup>1,2</sup> The statistics of the economic department of the town hall of Fez.

economic and social life of the city of Fez. They are about 10002 vehicles operating largely on the axis Bensouda district downtown. These are usually old Mercedes models (type 240 or 250, 280 or 300 mostly) that can carry up to six people maximum [8]. In terms of organization, the Ministry of Interior, through the services of the prefectures, controls the allocation of taxi licenses. This allocation method is twofold: first, to provide people with a public transport service and the other, "allow a category of low-income citizens, who have rendered outstanding services to the Nation or having a precarious social position, benefit from assistance from the administration (Circular of December 22, 1981, Home Secretary).

2) The transport by bus

This type of transport acquires more and more in life of the citizens due to its accessible pricing. In the city of Fez, the transport by bus is managed by the "City Bus" company. The contract of acting management spreads out over a period of 15 years renewable (Report acting management, on 2014). It urges the agent to invest about 430 million DH at the end of 5 years with objective to straighten the sector and to give a quality service to the inhabitants. Endowed with a park of 365 buses of medium and small size, the society exploits a network of 50 lines allowing the displacement of the inhabitants of Fez everywhere in the city. He also assures, via 10 lines, the service of the provinces of "Moulay Yacoub" and "Sefrou" as well as some villages raising main suburbs of the city of Fez. It is about 30 million passengers that are a year recorded (City Bus Society, 2015).

3) The informal transport

The insufficiency of vehicle fleet of common transport, which is exceeded with the population growth, the large influx of users during peak hours as well that the refusal of public transport operators to serve certain areas under pretext that they are not profitable. These factors pushed citizens to borrow emarginated vehicles of legality in unfavorable conditions that expose them to various risks. It is the informal transport.

**3 MODELING OF THE ACTORS OF URBAN PUBLIC TRANSPORT IN THE CITY OF FEZ**

The sector of urban public transports is characterized by the existence of a multitude of participants who contribute by far or closely to the management and the improvement of this sector. Before identifying the actors of the urban public transport of the city of Fes, it's logical to define first of all what that is a system of transport.

**3.1 Definition of a transport system**

A system can be defined as a set of element which work together and form a coherent whole. It performs functions to respond to a need for one or more users [18]. When we use the transport system, two main components are considered: the physical system and management system. The physical system is represented by two main elements: infrastructure and transport entities (bus, taxi, train, etc.). The management

system pilots the physical system so that it reaches its goals. Three types of actors so collaborate between them or interact within a system of transport: the users, the participants and the producers [17].

**3.2 Choice of modeling tools**

Functional modeling offers a range of tools which allow a graphical representation of the system studied in relation to its environment, hence the interest of a comparison of these tools in order to choose the most suitable to our study. These approaches include:

1. Pieuvre Diagram: After the APTE method (Application to Technical Corporate), it is a tool of representation of the functions of a system and their relations. It shows the associations between the elements of the surrounding environment and the system studied [18].
2. FAST Diagram: (Functional Analysis System Technique) is a graphic that device synthetically representing the hierarchical sequence of functions of repetition system "why / how / when" placed at each step of the analysis [18].
3. SADT Diagram: (Structured Analysis and Design Technique) is a diagram with downward box, part of the general to the private individual. Particularly adapted to the systems decomposable into money systems traveled by diverse flow [18].
4. SA/RT Method: (Structured Analysis - Real Time) is a method of analysis functional and operational which takes into account the dynamic aspect of the system analyzed. It allows a graphical and textual description of the system in terms of needs [19].
5. Diagram of relations: he highlights the multiple relationships between different components of a system [18].

Table 1 shows the grid of criteria for the selection of the right tool:

**TABLE 1**  
**MATRIX OF CRITERIA FOR FUNCTIONAL MODELING METHODS**

Choice	Criteria	Dedicated to the complex system	Ease of learning	Ease of use	Support software	Integration in other studies
Methods	Pieuvre Diagram	***	***	***	***	**
	FAST Diagram	***	**	**	*	**
	SADT Diagram	**	***	***	**	**
	SART Method	***	*	**	*	*
	Diagram of relations	**	***	***	**	*

Based on this comparative table our choice was based on the Pieuvre diagram. For it is accessible in terms of use and shows associations (functions) between the elements of the surrounding environment and the system studied.

**3.3 Methodology**

- 1) Presentation of actors

The urban transport-related governance is ensured by a number of organizations without adequate coordination between them, namely: the Ministry of Interior which is the main body of the administration and development of regulation), the Ministry of Equipment and Transport and Logistics, the town hall of Fez as a decentralized service of transportation by large and small taxis, urban Commune for the management of urban bus transport, urban Agency and safeguard Fez, the public transport company "City Bus", taxi unions, the Chamber of Commerce and Industry and the General Confederation of Enterprises from Morocco (CGEM).

2) Modeling of the actors

For modeling the functioning of the urban public transport system of the city of Fez, we opted for the Pieuvre diagram. The advantage of this functional description is to understand the structure and functioning of the system in relation with its environment. The method consists of three steps:

1. Identification of the system (in the center of the diagram),
2. Identification of the E.M.E. (Element of the Environment)
3. Identification and characterization of the relations of interaction (Ri) or at adaptation (Ra) between the system and the E.M.E.
4. Research for functions (FP1, FP2) and constraints (FC1, FC2).

Figure 2 illustrates the Pieuvre diagram of urban public transport sector in Fez:

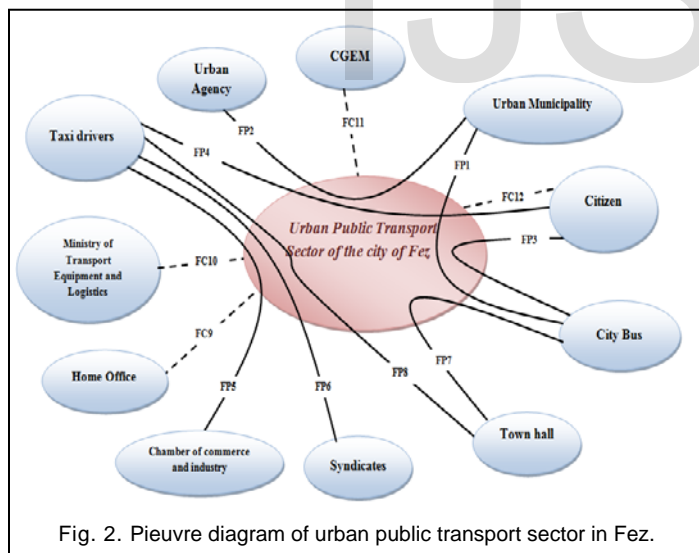


Fig. 2. Pieuvre diagram of urban public transport sector in Fez.

Table 2 shows the relationship between the urban public transport sector in the city of Fez and the different actors associated with.

4 IDENTIFICATION OF URBAN PUBLIC TRANSPORT PROBLEMS OF THE FEZ

TABLE 2

THE RELATIONS BETWEEN THE ACTORS OF THE URBAN PUBLIC TRANSPORT SECTOR IN THE FEZ.

Main Function
FP1: Ensure the development of public transit within its territory <sup>3</sup> . Control and monitoring of the implementation of the management contract <sup>4</sup> .
FP2: Offer the urban district technical planning assistance.
FP3: To provide citizens with transportation by bus.
FP4: Give citizens a transport service taxis.
FP5: Contribute to the improvement of the sector through mentoring and support of associations of small and large taxis.
FP6: Advocate for taxi drivers.
FP7: Coordinate with the urban municipality and City Bus to ensure the continuity and safety of the public service transport
FP8: Transportation Management by large and small taxi and control of licenses.
Constraint Function
FC9: Design, develop and implement the policy of the executive power regarding the supervision of local authorities <sup>5</sup> . Allocation control of taxi licenses.
FC10: Develop and implement the government's transport and infrastructure policy
FC11: Defend the interests of Moroccan companies
FC12: Use and consumption of the urban public transport service

To identify the problems affecting the urban public transport sector in the city of Fez, we conducted a survey through the development of semi-structured interviews with stakeholders including: the public transport company "City Bus "taxi unions, the Chamber of Commerce and Industry, the Urban Commune, urban Agency and backup of Fez and the town hall of Fez.

4.1 The semi-structured interview

1) Definition

The semi-structured interview is a data collection technology that contributes to development of knowledge promoting qualitative and interpretive approaches [20]. In general, the researcher has a number of themes or issues guides, relatively open, on which he wishes that the interviewee responds. But it does not necessarily ask all the questions in the order in which he noted them and under their exact wording [19]. It gives more freedom to the researcher but also to the respondent.

2) Interviewing

First, take a contact. Of course with people who might bring something to the survey, occupying different positions in the field of study [20]. After the first contact, we must justify our work and be as honest as possible. During the interview, avoid the journalist interviews and seek a discussion and an exchange of views based on objective facts from the survey and readings. Finally, try to transcribe so it can be understandable without changing the information gathered.

4.2 Structuring problems

To structure the problems obtained from the realized conversations, we have taken into account the complexity of the sector of urban public transport which articulates several dimensions and components (social, economic, institutional, and environmental, etc); we have also opted for the diagram

of Ishikawa. This tool allows a representation structured by all these components through categorizing them according to the rule of 6M: Environment, Subject, Material, Staff, Management and Financial means. The graphical representation of the diagram takes the schematic shape of a fish bone. The extremity represents the sector of urban public transport. The fish bones which converge on the central line, correspond to each one of the 6M, each of the latter includes extensions which represent the components of the studied sector (see figure 3).

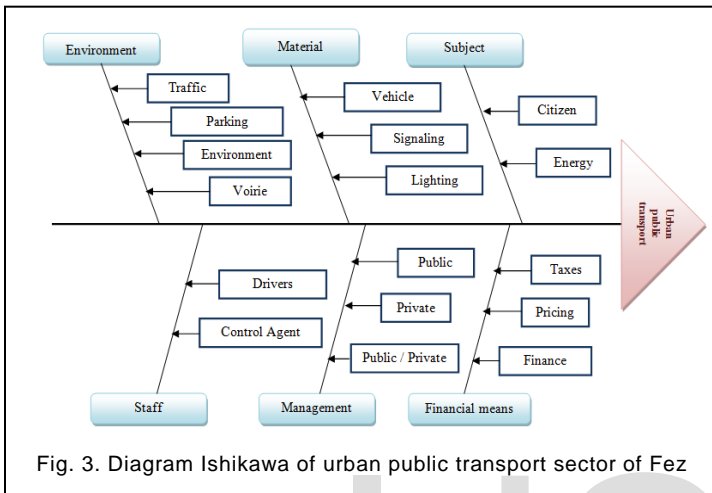


Fig. 3. Diagram Ishikawa of urban public transport sector of Fez

## 5 PRIORITIZATION OF PROBLEMS OF URBAN PUBLIC TRANSPORT SECTOR OF FEZ: USE OF MULTI-CRITERIA METHODS

### 5.1 Inventory of the multi-criteria analysis method

Multi-criteria Analysis is: "A technique dedicated to science clarification of understanding a decision problem and its resolution. It becomes multi-criteria when the problem involves several conflicting objectives and multi-decider, when several stakeholders have different views on the relevant objectives." [23]. Multicriteria aggregation methods are diverse and can be grouped into three main approaches [22]:

#### 1) Total aggregation approach

The object is to reduce all the criteria to be considered in a single quantitative criterion. It is assumed that judgments are transitive. Among these methods can be found, mainly:

1. Weight Sum Method (WSM): This method is the simplest of the Multicriteria methods. In this method, criteria should be quantitative, they all have the same

units and they extend on the same scale or range of values [22].

2. Weight Product Method (WPM): this method avoids certain defects of the weighted sum method [22] and is differentiated primarily by the following two points: The criteria (to be quantitative) can have values on different scales ranges from each other, so the actions that have a very low rating are heavily penalized. The principle of this method is to divide the values of all criteria by one of them and multiply these ratios.
3. Analytic Hierarchy Process (AHP): The AHP method invented and developed by Saaty aims to help actors in the decision making process to analyze complex problems by organizing and prioritizing information and assessments [23]. This method is to be a decision problem with a hierarchical structure reflecting the interactions between the various elements of the problem, then proceed with paired comparisons of the hierarchy of elements, and finally to determine the actions of priorities.

#### 2) Partial aggregation approach

This is a part of so-called upgrade methods, whose shares are compared to each other, two by two for each criterion. A summary of these comparisons is then performed [23]. Among these methods can be found, mainly:

1. ELECTRE methods: these methods have been developed by Bernard Roy [22]. Over history, to meet the requirements of different processes making, ELECTRE method was enriched. Today there ELECTRE I, II, III, IV and ELECTRE Tri. Thereof based on the comparison actions in pairs, require little information to be implemented so they provide strong but poor results.
2. The methods PROMETHEE (I & II): these methods have been developed by Jean-Pierre Brans and Vincke Philippe from 1980 [22]. They are based on the upgrade defined by Bernard Roy as in the case of ELECTRE methods.

#### 3) Local and iterative aggregation approach

Starting from a starting solution, the technique performs an iterative search to find a better solution [22]. In practice, these methods are based on complex mathematical theories, so we limit ourselves to list a number of interactive methods (PLM; Linear Programming Multiple criteria, STEM...).

### 5.2 Choice of multi-criteria analysis method

1) Comparison of multi-criteria analysis methods

The choice of the aggregation method is not easy. Some even think that we must go through a multi-criteria process to make a choice that is always unsatisfactory to provide a clear choice. In the light of the above-mentioned criteria, we will highlight the benefits, drawbacks and peculiarities of each method to pick the one that suits our object of study. Table 3 shows a comparison of total and partial aggregation methods previously treated [22].

TABLE 3

COMPARISON OF TOTAL AND PARTIAL AGGREGATION METHODS

Multi-criteria methods	Weighted sum	Multiplication ratios	MAAT	AHP	ELECTRE	PROMETHEE
Aggregation types	Total	Total	Total	Total	Partial	Partial
Data type	Quantitative	Quantitative	Quantitative and qualitative	Quantitative and qualitative	Quantitative	Quantitative and qualitative
Weighting	Yes	Yes (job/alternated)	Yes	Yes (normalized to 1)	Yes (except for ELECTRE 4)	Criteria to be considered in the order of preference expressed by the decision maker
Result type	Complete ranking	Complete ranking	Complete ranking	Complete ranking	No dominant Option: calculated value	Full ranking by use of six types of criteria
Advantages	Simple, known, no modification of the underlying problem	Clarity between the criteria, elimination of bad actions	Adapt to different criteria or scales units. It mathematically Represents the decision process	The only method to check the consistency of important relationships criteria. Flexible, diverse range of structured problems	First method of aggregate. Adapted to the problems of choice sets alternative	Method close to ELECTRE III but configurations restricted with physical quantities understandable for the decision-maker
Disadvantages	Best of the criteria, required by homogeneity of the units and by the scales of the criteria	Sensit values of the important criteria. Difficulty establishing the functions of utility	Not much intervention of the decision-maker. Difficulty establishing the functions of utility	The choice of scale from 1 to 9 is not mathematically justified	Effects of important thresholds. Modeling simple of the process of decision. Real Criteria only	Thresholds of indifference and rather constant. No notion of conflict

2) Why choosing the AHP method

Our choice based on AHP method (Analytic Hierarchy Process) for prioritization of urban public transport problems of the city of Fez was well justified, based on the advantages of this method despite its limitations. Thanks to its simplicity and ease of implementation, the method has been implemented in many aid software such decision (Expert Choice, HIPRE3+, which&why, Spreadsheets, Multsync). It helped to solve so many problems by developing a decision model for decision support, represented as a hierarchy [24].

3) The AHP method: Analytic Hierarchy Process

1. Presentation of the method

The AHP method consists of representing the decision problem by reflecting the structure hierarchical interactions between the various elements of the problem, then proceed with paired comparisons of the hierarchy of elements, and finally to determine the actions of priorities. This method is divided into three stages.

Step 1: corresponds to the decomposition of the decision problem in a structure hierarchical composed of elements and sub-elements [26] (See Figure 4).

Step 2: It consists of comparing together the various elements of a hierarchical level to determine its importance. The assignment of weight is carried out by comparing each of the pairs of "factors" and assigning a weighting factor to form a comparison matrix pairs.

Step 3: Determine the priority elements in first calculating the sum of the columns of the matrix, and then normalize the comparison matrix by dividing each element by its total column. Finally, priority corresponds to the mean of each row.

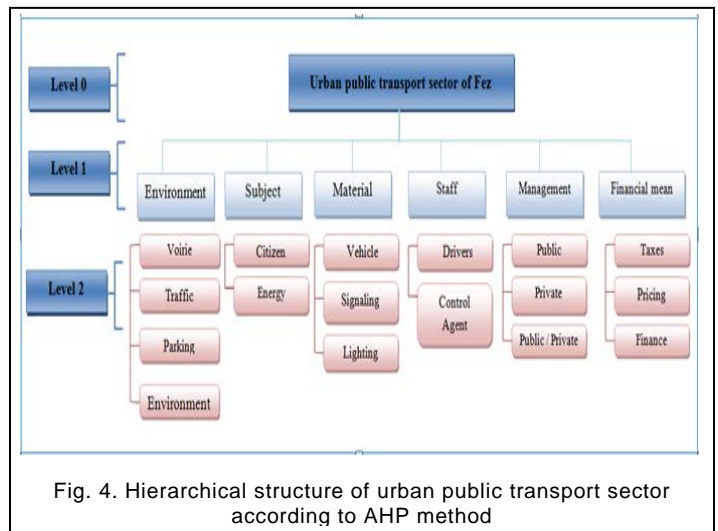


Fig. 4. Hierarchical structure of urban public transport sector according to AHP method

Step 4: Check the consistency of judgments.

First, we calculate the index of consistency IC:  $\frac{\lambda_{max} - n}{n - 1}$

Where:  $\lambda_{max}$  is the maximum proper value corresponding to the matrix of paired comparisons and n is the number of elements compared.

We calculate the ratio of coherence (RC) defined by:

$$RC = 100 \times \frac{IC}{ACI}$$

Step 5: Establish relative performance of each element.

4) Results

To effect calculations we used the Expert Choice software, in hired by the AHP method. After the decomposition of problems into a hierarchical structure, we established the comparison matrices in pairs for each hierarchical level and defined the relative importance of each element. The software automatically calculates the coherence indices associated with each comparison matrix to check the consistency of judgments. The exploitation of the AHP method to prioritize issues of urban public transport sector in the city of Fez, has given the priority for each axis shown in Figure 5.

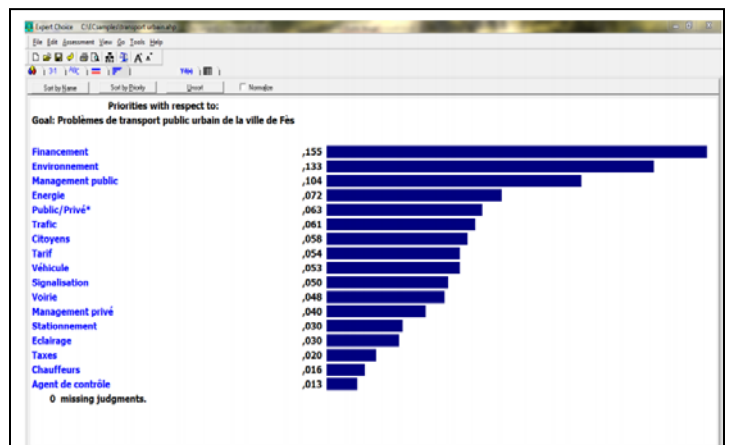


Fig. 5. Prioritizing axes of urban public transport sector of Fez.

5.3 ABC classification of the problems

Based on the results obtained, and to put the item on the most critical problems we opted for the ABC method. Also known as the "Pareto diagram" or "20/80 Rule", the method is a simple way to classify phenomena in order of importance. The principle of the method is the fact that 20% of cases produce 80% effect. So, just massive work on these 20% is necessary in order to strongly influence the phenomenon. In this sense, the Pareto chart is an effective tool for decision making. The Pareto offers classified in three groups: A, B and C.

1. Group A is composed of 20% of the causes constituting 80% of the effects of the phenomenon.
2. Group B is composed of 30% of the causes constituting 15% of the effects of the phenomenon.
3. Group C is composed of 50% of the causes constituting 5% of the effects of the phenomenon. So from the data collected, we define the categories, then:

TABLE 4

CLASSIFICATION OF CRITICAL PROBLEMS ACCORDING TO ABC METHOD

	Priority	%	Cumulative %	Classification
Finance	0,155	15,50%	15,50%	A
Environment	0,133	13,30%	28,80%	
Public Management	0,104	10,40%	39,20%	
Energy	0,072	7,20%	46,40%	
Private Public P	0,063	6,30%	52,70%	
Traffic	0,061	6,10%	58,80%	
Citizen	0,058	5,80%	64,60%	
Pricing	0,054	5,40%	70,00%	
Vehicle	0,053	5,30%	75,30%	
Signaling	0,050	5,00%	80,30%	
Voirie	0,048	4,80%	85,10%	B
Private Management	0,040	4,00%	89,10%	
Parking	0,030	3,00%	92,10%	
Lighting	0,030	3,00%	95,10%	
Taxes	0,020	2,00%	97,10%	C
Control agent	0,016	1,60%	98,70%	
Drivers	0,013	1,30%	100,00%	
Total	1,000	100,00%		

## 6 CONCLUSION

Despite its importance in daily life of citizens, the urban public transport sector suffers from several difficulties on several levels. This observation was confirmed by multi-criteria analysis that we conducted. To conduct this analysis, we initially identified the problems that the sector under question suffers from. This is based on semi-structured interviews with stakeholders and using the Ishikawa diagram; we combined and structured the problems identified. This work is followed by a hierarchy using the AHP method. Finally an ABC classification of the problems will find the most critical problems and solve those first.

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