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Mobility Analysis of the Population of Rabat-Salé-Zemmour-Zaer

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***Abstract*—**In this paper, we present the 2006 survey study origin destination and price that we carried out during 2006 fall in the area in the Moroccan region of Rabat-Salé-Zemmour-Zaer. The survey concerns the people's characteristics, their displacements behavior and the price that they will be able to pay for a tramway ticket. The main objective is to study a set of relative features to the households and to their displacement's habits and to their choices among public and privet transport modes. A comparison between this survey results and that of the 1996's is made. A pricing scheme is also given according to the tram capacity. (The Rabat-Salé tramway is under construction right now and it will be operational beginning 2010).

***Keywords*—**Matrix O/D, Theory of pricing, Urban transport survey.

I. Introduction

THE urban mobility and the displacement policies are a very strong indicator of the quality of life and of the economic and social evolution of our society. A better knowledge of the behaviours and practices of displacements are of primary importance for the organization and the planning of the transportation system.

This document is devoted mainly to the publication of the results of the 2006 origin destination and pricing survey conducted at the area of Rabat-Salé-Zemmour-Zaer. It concerns a descriptive survey study, whose main objective is to study a set of relative characteristics to the households and to the displacements made during one day of the 2006 fall season. We also investigate people choices among bus and tramway according to the distances to be travelled and to the tickets prices.

This document is divided into five parts. The first one is related to the characteristics of the survey and it briefly described the context of its achievement and the terminology used. The second part presents the socio-demographic data relating to the population and the territory of study. The third part is related to the study of the mobility at all the municipalities of the region. We take into account different parameters such as household's size, sex, age, car possession, driving license ownership, mode used, the motive for displacements, etc. This part contains also a comparison between the current results and those of the 1996 origin destination survey. The last part concerns the study of the tramway pricing and recommends a pricing scheme according to the tramway's capacity. This part provides also information making it possible to read and interpret people choices related to taking a bus or a tramway.

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II. Characteristics of the 2006 Survey Study

The 2006 survey study origin destination was performed on autumn at the urban area Rabat-Salé-Zemmour-Zaer. We choosed the autumn season for the survey since during this season there is some stability of displacements and of flow movements. Direct questions or telephone interviews were carried out for inhabitants of the survey study area. The main characteristics recorded by this survey study are:

- Origin and destination of each displacement;
- the mean and the reason of the displacement;
- mode or modes used for the displacement;
- buses lines used if any;
- choice between bus and tramway related to the itinerary travel distances and to tickets prices.

Some socio-demographic information (number of people by household, age and sex) that is essential with the weighting and the data expansion was also collected at the time of the survey study. The territory of survey study is limited to the urban areas of Wilaya of Rabat-Salé and mainly to the districts of the towns of Rabat, Salé, and with the municipalities of Témara Skhirate.

For Rabat, we consider the two municipalities Touarga and Hassan together because buses do not circulate inside of the first one. The municipalities of Youssoufia and Souissi are gathered under the name of Youssoufia since they are served practically by the same bus lines. Skhirate-Témara contains the municipalities of Ain El Aouda, Harhoura, Skhirate and Témara. Ain El Aouda designates its urban district and also the districts of Mers el Khaïr, Ain Atik and El Menzeh. The final list of the studied municipalities is:

TABLE I
List of Studied Municipalities

Rabat	Salé	Skhirate-Témara
Agdal Riyad	Bab Lamrissa	Harhoura
El Youssoufia	Bettana	Hssaine
Hassan	Hssaine	Skhirate
Souissi	Layayda	Témara
Y.El Mansour	Tabriquet	

The 2006 survey study origin destination is based on direct or telephone interviews.

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We considered seven years groups of age: 0-14, 15-19, 20-24, 25-34, 35-44, 45-64 and more 65 years. People activities were classified into four groups: worker, student, retired and other. The destinations are work's place, study's place or other. For each destination it is necessary to specify the municipality. The travel reasons stated by the interviewee were grouped in four categories: work, study, leisure and other. The transport means used by the interviewees were grouped in six categories: Walking, 2-wheels, Car, Taxi, Big taxi, Bus and Other.

For those using a car, the drivers are themselves, their spouse, or others.

The travel distances of displacements considered are three kinds: Less than 5Km, Between 5 and 10 km and greater than 10 km.

The questionnaire is summarised by the following table:

TABLE II
QUESTIONNAIRE CONTENT

Household	People	Displacements	Pricing
• Number of people • Number of cars • Numbers of two wheels • Habitation Place before 5 years.	• Sex • Age • Driving licence • Activity • Study or work location	• A number of exits • Origin • Destination • Motive • Departure time • Return time • Transport means • Bus lines used • Distance • Correspondence • Car's Occupancy • Parking	Choice between: • Public or private transport means • Bus and Tramway related to distances and travel costs

III. STATISTICS OF THE POPULATION OF THE AREA

The automobile park in circulation in Morocco progress with an average rate of 5.4% per year [6]. On the average 70000 vehicles are added each year between 1990 and 2002. This rate is exactly twice as large as the rate of population increase for the same period that is 2.7%.

The study of the area population is a key factor explaining the mobility of its inhabitants. This study is mainly based on 1994 and 2004 censuses [2], for the determination of the forecasts of the populations and the households for both 1996 and 2006 years. The results as well as the annual rate variations of the population and the households for years 1996 and 2006 are presented in Table III. They concerned the towns of Rabat, Salé and Skhirate Témara and for the total population of the studied area.

The increasing rate of Rabat population is very low compared to those of Salé and Skhirate-Témara. Indeed Rabat underwent an increase of 0.1%, whereas urban population of Salé underwent an increase of 31% and that of Skhirate - Témara an increase of 64.5% (Table III). These phenomena can be explained by the important rural migration to Salé and Skhirate Témara cities. And also, by the great number of Rabat inhabitants who moved to these two cities. We found that this moving state from Rabat to Salé or/and Skhirate-Témara during 1996 to 2006 period is caused by the fact that the residences became increasingly rare in Rabat downtown and their prices underwent a great increase whereas in Salé and Skhirate Témara the prices were promising.

The following graph shows the population evolution by municipality between 1996 and 2006:

TABLE III
POPULATION FORECASTS

Municipality	1996	2006	Increase
AGDAL RIYAD	77056	94301	2,04%
ELYOUSSOUFIA	196185	201197	0,25%
HASSAN	150407	131251	-1,35%
Y. EL MANSOUR	200197	202830	0,13%
BAB LAMRISSA	118947	146320	23,01%
BETTANA	102346	103371	1,00%
HSSAINE	87603	191354	118,43%
LAYAYDA	89753	126666	41,13%
TABRIQUET	210531	241206	14,57%
AIN EL AOUDA	44301	69180	56,16%
HARHOURA	6876	9955	44,77%
SKHIRATE	31898	46367	45,36%
TEMARA	145846	251450	72,41%

As conclusion of this part, we can stated that the increasing annual rates about the total population of the area related by this study from 1996 to 2006 and respectively to those of the cities concerned are:

- Total area : 2.06 %
- Rabat : 0.10 %
- Salé : 2.74 %
- Skhirate Témara : 5.10 %

IV. STATISTICAL TABLES OF THE RESULTS OF THE SURVEY STUDYS 1996 AND 2006

The following table presents a general description of the residents' mobility in the surveyed area. It is related to the:

- "Number of mobile people" (number of people who move on a labour day);
- "Number of displacements performed by residents";
- "Number of non mobile residents";
- "Average number of displacements per people".

This mobility is shown for the 1996 and 2006 years by Table IV. We notice that during this time the number of mobile people increased by 72%, which corresponds to 5.5 % as an annual increasing. The number of displacements is following practically the same evolution, while the number of non mobile people underwent an important reduction around 9

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% each year. The average number of displacements per people underwent a little increase. This average changed from 1.54 during 1996 to 1.62 in 2006.

TABLE IV
MOBILITY FROM 1996 TO 2006

General portrait	1996 (10^3)	2006 (10^3)	Total % Variation	Yearly % variation
# of mobile people	968	1661	71,6%	5,5%
# of displacements	1489	2695	81,0%	6,1%
# of not mobile people	404	159	-60,7%	-8,9%
Average number of displacements	1,54	1,62	5,5%	0,5%

A. Origin Destination Matrices

Origin destination matrices are presented bellow for the 1996 survey study and for the 2006 one.

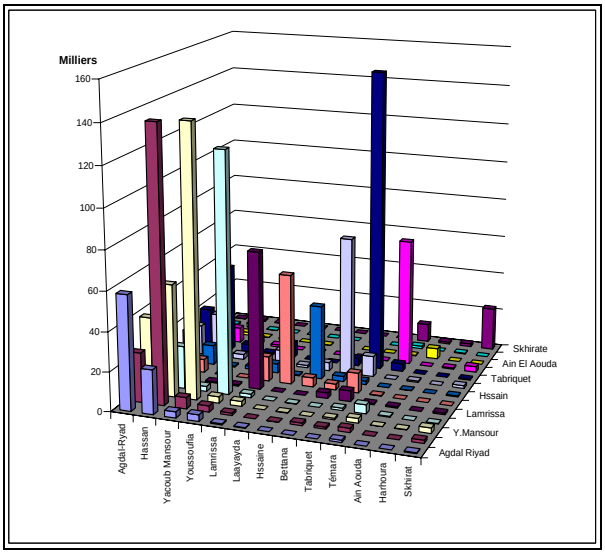


Fig. 1 Total numbers displacements between the various municipalities in 1996

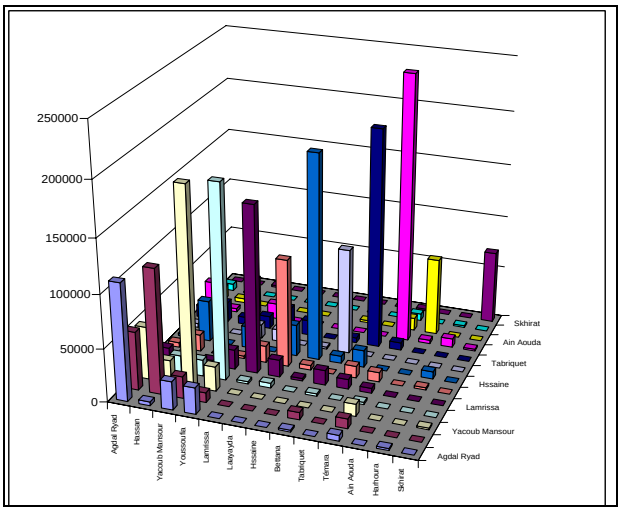


Fig. 2 Total numbers displacements between the various municipalities in 2006

We notice that the numbers of displacements inside of the same municipality are the most important ones. They are represented by the first diagonal of the base of the figure. Their travel distances are in general small. They are smaller than the municipality's wide. Most of these travels are carried out by walking.

B. Displacements According to the Mode Used

We explored the displacements respectively to their mode as seen in Figs. 3 and 4.

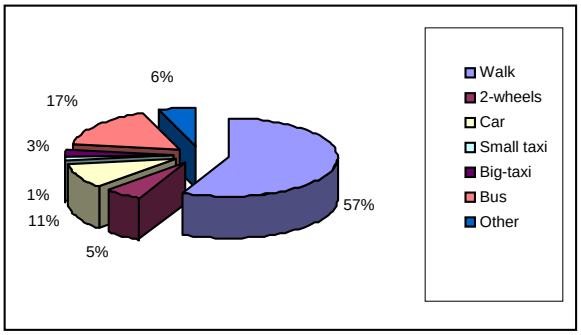


Fig. 3 Distribution of 1996 displacements according to the traveling mode used

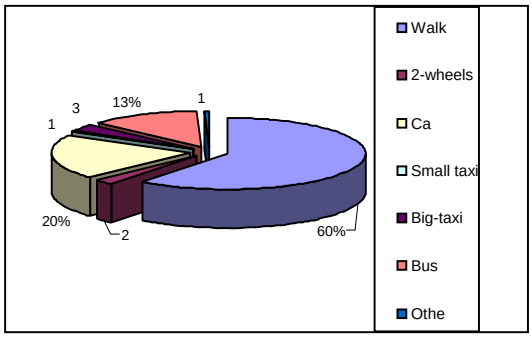


Fig. 4 Distribution of 2006 displacements according to the traveling mode used

The percentage of inhabitants using two wheels decreases by 3% from 1996 to 2006. These phenomena can be explained by the road insecurity for the two wheels users. In fact, according to the Direction of the Roads and the Road traffic (DRCR) of Morocco; on 2004, 80.7 % of mortal road accidents in agglomerations are auto-cycle riders. The tendency worsened with an increase of 17.82 % during 2005.

The modal share of the bus was reduced almost by 4%, this event may be is the consequence of the bad condition of the buses park and of the bad quality of the service offered. On the other hand the traveling car mode increased by gaining 9.4% of the displacements in the area. This phenomenon is due to the increase in the private cars park.

The percentage of the mode of displacement "other" underwent an important reduction of 5%. Indeed this mode includes all organized displacements of the personnel by employers, displacements not motorized, informal modes, carts and other old-fashioned means of displacements. This

fact can be explained by the removal of the official cars from most of the public administrations and by the reduction of the number of carts and their regulation in Salé and Skhirate Témara.

C. Displacements According to the Motive

Displacements according to the motive for the two survey studies are presented by Fig. 5 and Fig. 6 .

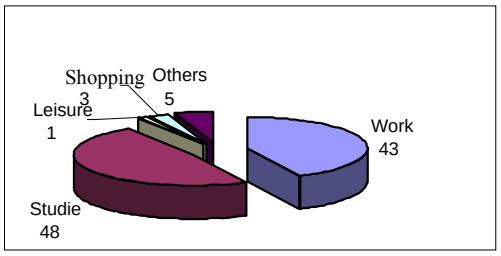


Fig. 5 Distribution of 1996 displacements according to the motive

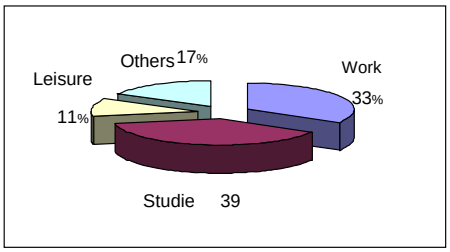


Fig. 6 Distribution of 2006 displacements according to the motive

From these two figures, we notice that the percentages of the displacements for work underwent a reduction of 10% and those for study a reduction of 9%. We can explain this decrease by the institution of the continuous timetable at most of the public administrations and at several establishments of the primary and secondary education.

On the other hand the percentages of displacements for leisure and the other motives increased. For leisure, we can say that since the workers and the employees leave work toward 16h30, they can go out again for shopping or for leisure after work. Besides that, we also note it at the time of the interviews a large number of people say that after work, they either to go to coffee place, to meet some friends, or to do shopping.

The reduction of the displacement percentages for work and for studies after the institution of the continuous timetable should represent almost 45%, if we based ourselves on the percentages of the displacements by motive on 1996. However, this reduction is only 19% because the continuous timetable is not generalized everywhere, especially at the private and education sectors. According to the results of 2006 survey study, the percentage of the workers that adopted the continuous timetable is 58.6 % and the percentage of the displacements for work done by the workers who follow the continuous timetable is 41.4 %. Regard to the motive for studies, these percentages are weaker, the percentage of the students that adopted the continuous timetable is of 16.6 % and the percentage of the displacements done by these same students is of 9.0 %.

V. Study of the Tramway Pricing

A. Choice between Public and Private Transport

During the interview, we asked the following question: if you have a private mean of displacement which one will choose; yours private one or the public transport?

This question is given to have an idea about the attractiveness of the tramway and the bus.

We notice that a large percentage (84 %) of the area's population prefers the private transport versus the public one.

When the tickets prices for the tramway and the bus, the choice made is practically 100% for the tramway. This is evident as the tramway is faster and more comfortable than the bus.

Assuming that the tramway ticket costs 6 DH and that of the bus costs 4 DH, almost 60 % of the inhabitants of the survey study area choose the tramway. We observed only a small preference towards the tramway when the travelled distance increases. This can be explained by the fact that inhabitants are not taking care of time saving carried out by using the tramway instead of the bus for larger travelling distances.

Finally in the case, when the tramway ticket costs 8 DH and that of the bus costs 4 DH, nearly 20 % of the inhabitants of the area choose the tramway. When their travelling distance is lower than 5 Km, This percentage rises slightly when the distance increases.

B. Choice between Two Buses, Two Tramways or a Bus and a Tramway

In the following tables, we represented the choices of the inhabitants of the survey area when they have to use two means of transport to travel. These means are either two lines of buses, two lines of tramways, or a line of tramway and a line of bus.

We notice that when the tickets of the tramway and the bus are identical; the travellers choose two tramway lines.

When the ticket of the tramway costs two dirhams more than the bus ticket; 44% of the travellers choose 2 tramways and almost the same percentage of the travellers choose 2 buses and nearly 12% choose a tramway and a bus. These choices are practically independent of the travelled distances. When the ticket of the tramway costs twice as expensive as the bus ticket; the percentage of the travellers who choose 2 tramways is between 20% and 22%. 70% to72% of the travellers chooses 2 bus and only 7% choose one tramway and one bus. These choices vary slightly between 0% and 2% according to the travelled distances. In fact, when the distance increases; the rate of two tramways users' increases and that of the two buses users decreases.

C. Study of the Tramway Ticket

The next Fig. 7 illustrates the choice between the tramway

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Open Science Index, Humanities and Social Sciences Vol:1, No:9, 2007 publications.waset.org/12442/pdf

and the bus according to the cost of the tramway ticket when the distance exceeds 10 km.

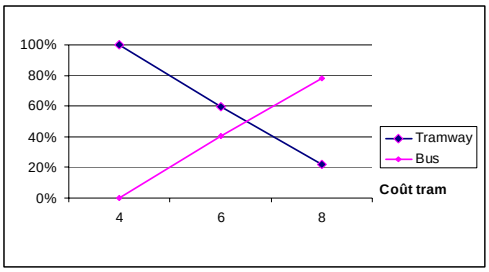


Fig. 7 Choice between tramway and bus when the distance is between 5 and 10Km

This graph shows that when the tramway ticket costs 6 DH the share of displacements by tramway is 60 % and that of the bus is 40 %.

To determine the convenient cost to apply for the tramway ticket in order to maximise the tramway company benefits, it would be interesting to compare the share of displacements between the tramway and the bus. For this purpose, we studied first the travel demand on the different sections served by the tramway. Second, we determined the percentage of travellers whom we will be able to assign to the tramway according to its capacity. And finally, we will compare this percentage to the share of displacements by tramway revealed by the survey.

To this end, we perform the following computations:

Let designate a tramway line T and c the capacity of all its vehicles. We shall assume that the tramway passes by zones 1, 2,..m and that dij are the displacements demands from zone i towards zone j.

The da is the total displacement demand that could be carried out by the line T on the outward journey in direction of 1, 2..m. In the opposite sense dr denote the return demand by that line.

$$da = \sum_{i=1}^{m} \sum_{j=i+1}^{m} d_{ij} + \sum_{i=1}^{m} d_{ii}/2$$

We suppose that half of the demand of displacements expressed inside a zone will take the direction on the outward trip and the other half will take the other direction. Thus for each i the demand of displacements to go inside zone i is $d_{ii}/2$ and it is equal to that one of the return inside zone i.

We also suppose that all the travellers coming from the i zone will catch the tram at its first stop at that zone; those who will end their trip at i zone will alight the tramway at its last i zone stop, and those whose destination is at j zone will alight at the first j zone stop.

These assumptions simplify the line of the tramway, which can be made up just by two kinds of sections or arcs: arc inside a zone or arc between zones i and zone i+1. Arc inside zone i will be noted (i,i) and that between zone i and zone i+1will be noted (i,i+1) for i=1,2..m.

Thus the tramway line will have just two stops at each zone. They will be noted i1 and i2 for i = 1, 2,… m.

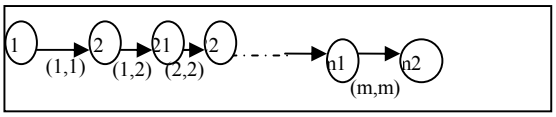


Fig. 8 Simplified path of a line of tramway

The traveller numbers or the tramway demands from zones i towards zone i with the outward trip is dat_{ii},, where dat_{ii} is:

$$\mathbf{dat_{ii} = d_{ii}/2 + \sum_{k=i+1}^{m} \sum_{l=1}^{i} d_{lk}} \quad \text{for } i < m$$

$dat_{mm} = d_{mm}/2$

The traveller's number or the demand of the tramway from i zone towards i+1 zone with the outward journey is dat_{ii+1} where dat_{ii+1} is: $\mathbf{dat_{ii+1} = \sum_{k=i+1}^{m} \sum_{l=1}^{i} d_{lk}}$ for $1 \le i < m$

We can see that $dat_{ii} \ge dat_{ii+1} = dat_{ii} - d_{ii}/2$

Let $\mathbf{dat^* = \sup_i \{dat_{ii}\}}$

Where dat^* represents the maximum number of travellers on all the arcs of the tramway line with the outward journey.

If the tramway vehicles accomplish r outward journeys and r returns; its capacity for one day is rc for both direction. The percentage of the demands for displacements that the tramway can support with the outward journey noted pda is 100 % if $dat^*/r \le c$, and it is less than 100 % if $dat^*/r > c$

Next, we will determine pda when $dat^*/r > c$. For that, we will proceed as the following way:

Beginning by i=0 , i= i+1, $dan_i = \sup(0, dat_{ii} - rc)$

Here, we assume that the numbers of displacements inside of the same municipality are the most important ones. They are represented by the first diagonal of the base of the figure. Their travel distances are in general small. They are smaller than the municipality's wide. Most of these travels are carried out by walking.

The non supported displacements by the tramway are proportionally distributed to the values of the demands sections (i, j) for j = i, .. to m. We calculate the non supported displacements between zones i and J which is pan_{ij}.

$pan_{ii} = dan_i * (da_{ii}/2)/dat_{ii}$ and $pan_{ik} = dan_i * da_{ik}/dat_{ii}$ for k>i

So that dan_i ,the non supported demand on the section (i, i) is:

$$\mathbf{dan_i = \frac{dan_i \times da_{ii}}{2\, dat_{ii}} + \sum_{k=2}^{m} \frac{dan_i * da_{ik}}{dat_{ii}} = \sum_{k=1}^{m} pan_{ik}}$$

d_{ik} will be replaced by $d_{ik} - pan_{ik}$ for k = i,2. .m and d_{ii} by $d_{ii} - 2*pan_{ii}$. We calculate:

$$\mathbf{dat_{jj} = d_{jj}/2 + \sum_{k=j+1}^{m} \sum_{l=1}^{j} d_{lk}} \quad \text{for } j = 2..\ m$$ so that dat_{jj} will be

replaced by : $dat_{jj} - \sum_{k=j+1}^{m} pan_{lk}$

Then we will replace i by i +1 and we proceed as before until i = m.

Finally the total demand not supported by the tramway to

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the outward journey is: $\mathbf{dan} = \sum_{i=1}^{m} \mathbf{dan}_i$

The percentage of the demands for displacements which the tramway can support with the outward journey is

pda = (da - dna) /da

By the number of displacements not supported by the tramway with the return back travel is: $dnr = \sum dnr_i$

The percentage of the demand for displacements which the tramway can support with the return back travel is:

pdr = (dr - dnr) /dr

The following flow chart will determine the number of displacements not supported by the tramway to the outward journey:

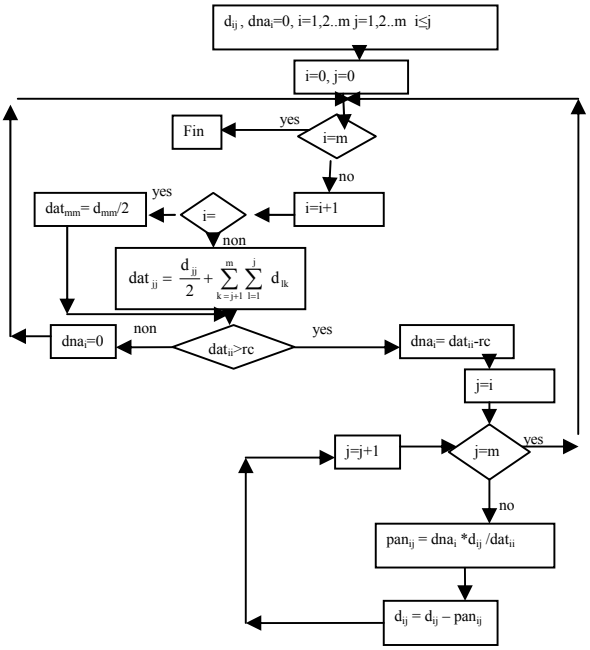


Fig. 9 Flow chart of the determination of the displacements not supported by the tramway on one way

Finally, the percentage of the total demand for displacements that the tramway can support is given by:

$$pd = \frac{[pda * da + pdr * dr]}{da + dr}$$

According to 2006-survey study results the figure 7 shows that if the tramway capacity can support just 60% of the passengers, it will be profitable to set up the ticket cost of the tramway at 6 DH level. On the other hand if this tramway capacity supports just 20% of the passengers, it would be advantageous to fix the cost of the tramway ticket at 8 DH.

The following figure shows the choice according to the cost of the tramway ticket between 2 tramways, 2 buses or a tramway and a bus when the distance exceeds 10 km.

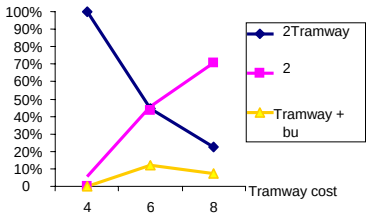


Fig. 10 Choices between 2 tramways, 2 buses or a tramway and a bus according to the tramway ticket for distance> 10 km

Fig. 10 shows well that the price of the ticket of the tramway ticket as 6 DH represents a critical point. Beyond this threshold, the attraction of the tramway is lower than that of the bus.

If the capacity of the two lines of the tramway makes it possible to support 40% of the passengers, it would be advantageous to set the cost of the tramway ticket at 6 DH. If the capacity of the tramway makes it possible to support just 20 % of the passengers, it will be more advantageous to set the cost of the tramway ticket at 8 DH.

We can also represent the tramway receipt according to the tramway capacity and see whether it would be advantageous to increase this capacity or not.

VI. Conclusion

Nowadays, the mobility management is a major political stake. By this study, the policy of mobility in the area of Rabat-Salé-Zemmour-Zaer will have a large vision of inhabitant's displacements and a comparison between 2006 situation of mobility and that of 1996.

The no existence of reliable and complete data on mobility in Morocco for a long time had let the deciders making decisions on the basis of older ideas, or received suggestions, rather than on real facts. These surveys in particular show the important rate of displacements between the habitation and work or school which is between 72 and 90 %. It also illustrates the strong proportion of the population, which was at 28 % on 1996 and that underwent an important reduction during 2006 of almost 9 %.

The current tendency found is a higher increase in the urban displacement demands with a main trend towards private transport. It is necessary to hand over clear objectives with transport on common running within the framework of urban developments and ground occupations. Initially, it is necessary to set the share of urban displacements, which must be supported by public transport. The part of transport by bus is very low, 17 % on 1996 and it decreased to 13 % on 2006. This suggests that this sector must become more effective to offer to the customer a better service, in quantity and quality. It is also necessary to set the share of urban displacements which must be supported by public transport. This share is to be determined according to conditions of complementarities with the private car. The goal is being minimizing the congestions, and to optimizing the use of the existing infrastructures. We studied the tramway pricing according to a trip that need just one tramway or bus line and the trip that

needs two means of public transport line.

Finally, this study makes it possible to determine the cost of the tramway ticket according to the capacity offered by the tramway line.

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