

CHOICE OF INDICATORS OF SUSTAINABLE URBAN MOBILITY FOR CASABLANCA AND CALCULATION OF SOME INDICATORS USING A GEOGRAPHICAL INFORMATION SYSTEM

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ABSTRACT

Sustainable transportation is a direct expression of sustainable development in the transport sector. The urban transport planning must consider the four pillars of sustainability: economic, social, environmental and institutional. Casablanca, like many cities in developing countries experiencing a rapid urban growth with a great difficulty to ensure the urban transport services. Therefore, there is a low part of public transportation in the urban mobility, against a big demand on the private vehicle beside a significant presence of informal transport. This complicates the planning effort maintained by the actors in the city that provide significant efforts to ensure the operational management of urban transport. This work aims to strengthen the position of sustainability in the planning process undertaken in Casablanca. Thus, we propose to analyze, compare, and choose a set of sustainable mobility indicators adapted to the context of Casablanca including offer, demand, economic, social, environmental and governance indicators. These selected indicators are also a tool for data collection and measurement on sustainable mobility in the urban area of Casablanca. We also use a Geographical Information System environment in order to integrate public transport data and offer maps in addition to population data into a Geodatabase. Spatial analysis helps us to compute a set of selected indicators especially those related to the offer and social issues. This indicators system was used, to show the unsustainability of the urban transport system of Casablanca.

Keywords: *Casablanca, Sustainable Mobility, Indicators, Urban Planning, Geographical Information System.*

1. INTRODUCTION

The research for sustainability started by general economic development, but it was quickly declined by particular fields and we are talking about sustainable transportation, sustainable city, sustainable urban, sustainable development of territories, sustainable mobility ... etc.

Sustainable development made its first appearance in 1987 in the Brundtland report (World Commission on Environment and Development). The report of this commission proposed as definition: "Sustainable development is meant to meet the needs of the present without compromising the ability of future generations to meet their own needs" [1].

The needs of which we speak are of different natures, in fact: "sustainable development meets the needs of the present without sacrificing the ability of future generations to do the same. These 'needs' are now widely accepted to include goals related to economic development, social and human development, and environmental and ecological health. In the context of natural resource policy, sustainability would mean limiting depletion of resources to the rate at which they can be replenished, or alternatives can be identified" [2].

Almost three decades after its appearance this concept still poses problems of definition and meaning" [3].

It is currently noted that the "sustainable" quality is

linked to all public policies and to all productive

sectors: sustainable tourism, sustainable industry, but also sustainable transportation, sustainable city, sustainable development, sustainable urban, sustainable mobility ... etc.

In Morocco, it was in 2000 that the term "sustainable development" was used for the first time in an official document, for the "territorial planning charter".

Little time after the appearance of the notion of sustainable development, its decline in the form of sustainable transportation appeared. The first definitions of sustainable transportation were obviously an application of the definition of sustainable development on transportation: "By modifying the Brundtland Commission's definition of sustainability for the planet, we can derive a definition of sustainable transportation as the ability to meet today's transportation needs without compromising the ability of future generations to meet their transportation needs" [4] - [5].

Sustainable transportation addresses local, regional, national and global issues and imperatively necessitates an important coordination.

The first definitions of sustainable transportation have just to consider environmental impacts without compromising economic objectives. The solutions then proposed by transportation specialists were of the type: coordination of traffic lights, changes to the Highway Code and zoning laws, corridor development, construction and optimization of new infrastructures, the development of fast lanes, the increase of public transportation services and the development of intermediate networks. [6] - [7].

Thus, the sustainability is sought by the various actors of transport: "The future of comprehensive public transportation network construction ... is focused on how to make public traffic modes more sustainable and how to improve the traffic accessibility ..." [8].

There is also the OECD definition (2000) which specifies that "the issues to be taken into account in this regard include the reduction of carbon dioxide emissions, the control of consumption rate of non-renewable fossil fuels, and the limitation of lands use and other non-renewable resources for the

construction of infrastructures and transportation vehicles" [9].

What can be noticed is that whatever the proposed definitions of sustainable transportation, they frequently refer to the triple essential fields of the economy, the environment, and the sustainability of social equity [5] - [10] - [11]. An expected sustainable mobility's role is to meet the basic access and development needs of individuals, companies and corporations, safely and in a manner consistent with human health and ecosystems. It should be ensured with equity for all next generations.

2. STUDY AREA

2.1 Casablanca: Populated City, Young, Active and Wealth Producing

Casablanca is the biggest metropolis of Morocco and one of the biggest metropolises of the African continent. Casablanca region covers 1615 km² with nearly 4 million inhabitants including a good part of the young population (31% are under 15 years old). Casablanca is also a very active city with an activity rate of 51%. It hosts 39% of Morocco's productive units and 60% of the industrial workforce.

The port, which has been the catalyst for the development of the new city of Casablanca since the beginning of the 20th century, still plays a key role in the Moroccan economy. Indeed, 55% of the country's trade's flows through this port. In addition, Mohamed V airport accounts for 51% of the total national air traffic.

Thus, Casablanca alone generates 25% of the national GDP, attracts 48% of investments and has 30% of the banking network.

This powerful participation in the Moroccan economy has been accompanied by a strong urbanization and, above all, a significant demand for urban travel.

The population of Casablanca region (Casablanca, Mediouna, Mohammedia and Nouacer) increased from 3.1 million in 1994 to 4.1 million in 2012, a 33% increase in 18 years (1 million inhabitants furthermore). Also, this population is more than 96% urban according to 2004 statistics.

The city of Casablanca is also characterized by a high density in the center in comparison with cities of the same size. But this characteristic is currently combined with urban sprawl becoming more important.

The current political will is to delimit the extension of the city of Casablanca by an urban bypass and a green belt with the major objective of stabilizing its population. In return, it is proposed a growth around Casablanca Mohammedia by developing nine peripheral urban poles: Dar Bouazza, Errahma, Bouskoura, Nouacer, Mediouna, Lahraouiyyine, Tit Mellil, Zenata and Beni-Yekhlef according to the master urban plan of Casablanca, published by the urban agency of Casablanca in 2008.

2.2 The Evolution of Mobility in Casablanca

This rapid growth of the population and urbanization of Casablanca region has resulted in a sharp increase in the demand of mobility. Thus, urban mobility in Casablanca increased from 1.6 trips per person per day in 1976 to 2.9 trips per person per day in 2004, which corresponds to a total number of trips that increased from 4 million to 10.4 million per day between these two dates.

In 2004 the Casablanca city car fleet reached 335,000 vehicles (705,000 vehicles for all Casablanca region). Also, the car fleet increased significantly between 2004 and 2012 in all Casablanca region, and reached 1.2 million vehicles, which represents 34.5% of the national car fleet in Morocco. Thus, the motorization rate of the all Casablanca region is today about 270 vehicles per thousand inhabitants, which represents more than twice the rate of the national motorization rate.

However, it should be noted that one of the most important reasons for this development of the car fleet in Casablanca is the low public transport offer. This weakness does not only affect the quantity of the offer but also the quality of the services offered.

Regarding the modal split, the Urban Travel Plan of Casablanca showed that walking is the most used mode in 2004 with 53% of the total number of trips. It is followed by the car which accounts for 14.5% of trips. Public transport (buses) accounted for 13%, followed by collective and urban taxis, which accounted for 10.3% and 5.2% of trips, respectively. Finally, the two wheels represent for 4% of total trips.

The car plays an important role in urban travel in Casablanca, with all the problems associated with the negative effects of this mode (environmental impacts, congestion, car accidents, etc.) and high direct costs for road car users.

The "choice" of the model of urban sprawl around Casablanca on nine peripheral urban poles, will increase the road traffic. The examples of other peripheral urban poles made in Morocco (Tamesna and Tamansourt), which are considered to be "dormitory" cities, at least up to now, confirm this risk for the Casablanca model.

3 CONTEXT AND OBJECTIVES OF THIS WORK

3.1 Context of This Research

This work is included in a large research which aim to study the interaction between urban development and sustainable mobility in Casablanca, and more particularly the effect of urban development and planning policies on the peripheral districts and the specificities of their disadvantaged population. Especially, a household survey focusing on the mobility of disadvantaged households in the peripheral districts of Casablanca is currently being finalized.

So, the proposed indicators will be used later to study and explain the mobility of disadvantaged populations in the peripheral districts of Casablanca.

3.2 Objectives of This Research

The main objective of this research in to develop a series of indicators that allow considering all aspects of mobility related to sustainable development: environmental, economic social and governance dimensions of the daily mobility of the Casablanca inhabitants.

In addition, we will propose an analysis of the supply and demand of urban public transport in Casablanca region.

These indicators will allow to measure the impact of this mobility in the light of this urban sprawl of Casablanca. and to know at what "price" urban sprawl in Casablanca is paid in terms of mobility.

Within this research we will also focus on calculating some of the proposed indicators. This calculation will be done in a Geographic Information Systems (GIS) environment. Indeed,

GIS “are providing valuable information for the urban extension for policy and decision makers” [12].

Equitable-spatial distribution is a significant component of urban planning which should be guided by sustainable development strategies [13], GIS analysis will help us to verify this equitability of the spatial distribution in the territory of Casablanca for the case of urban public transport.

4 METHODOLOGY

Indicators are "variables developed and selected to meaningfully describe a salient element of a given social concern." Quantitative or qualitative, these variables can describe a situation or trend and measure actual facts in absolute or relative value [14]. Each type of indicator provides specific information about the entity under consideration.

The approach retained is that of "sustainable development", which proposes a grid of three-dimensional environmental, economic and social reading of the phenomena observed as explained above.

It is therefore important to develop indicators, related to these dimensions, by defining a field of observation which is coherent both in terms of the explanatory factors of the activity considered and the level of the decision-making powers involved. [15]. Similarly, the issue of governance deserves to be considered within the indicators, even at a qualitative level.

Thus, the indicators must allow to:

- Reflect on the long-term impacts of an urban transportation policy,
- To account for the issues posed in each of the economic, environmental and social dimensions, constitutive of any organization of transport within a city.

Besides, the will to implement indicators implies twice effort. On the one hand, the question of the relevance of these indicators is based on a good appreciation of the issues to be retained in terms of the sustainable development of the urban mobility system. On the other hand, it is important to provide all the necessary elements to understand the construction of the retained indicators and to ensure their measurability over time and their scalability.

An in-depth study of the various works to define indicators of sustainable mobility in different contexts was carried out.

The choice of some indicators to retain is made considering the specificities of the city of Casablanca.

For environmental issues: we can retain:

- Issues of energy consumption and greenhouse effect,
- Local atmospheric pollution issues
- Challenges in terms of the occupation of space by infrastructures and by different modes.

For the economic issues, the challenge is the search for the economic efficiency of the system of displacements in Casablanca by observing as much as possible:

- The total cost of displacements (displacements accounts)
- The appreciation of the cost per type of displacement.
- Cost per type of population and area of habitat

For social issues: We can retain as main objective the social equity. In fact, the problems of disparity and significant difference in terms of wages have involved a very strong marginalization of part of the population. This marginalization is also explained by strong inequalities in motorization and access to the car. Its effect appears on the modes used and the costs and time spent on travel due to the very varied financial constraints of the population.

Thus, we must consider typologies of individuals and households in order to be able to analyze the differences in mobility according to their characteristics and the constraints that may be related to them (location of the home and workplace, access to different modes, socio-demographic status and income).

Governance issues: we also think it is important to add some indicators on the governance of urban transportation, which could also consider a certain number of information such as the type of governance, the clarity of governance, the mode of practice of this governance, ...etc.

The system of indicators must also consider the situations of transportation offers and demands in the city, car it is the starting point of any desire to

appreciate mobility in a city or to make it evolve towards a more sustainable system.

Concerning the calculation of some indicators for the case of Casablanca we used a GIS environment. We acquired spatial data related to the territory of Casablanca, including administrative division and public urban transport network. We also used socio-economic data on Casablanca's population.

All these data were integrated in a geodatabase and analyzed using ESRI GIS (ArcGIS environment). We used spatial analysis algorithms to spatialize these indicators. At the end we prepared maps to illustrate the results.

The choice of GIS environment is very adopted to support urban transport analysis. Indeed, many studies uses GIS framework to perform indicators based analysis of urban transport sustainability, like the case studies of Nanjing City in China [8]. and Edmonton in Canada [16].

5 RESULTS: PROPOSAL OF SUSTAINABLE MOBILITY INDICATORS FOR CASABLANCA

5.1 Offer Indicators

- Capacity of transportation infrastructure networks, by mode and type of infrastructure (roads, railways, motorway, etc.).
- Capacity of urban public transportation (Bus and tramway) and capacity of artisanal transportation.
- Infrastructure investment, per person and per mode.
- Number of bus vehicles per million inhabitants and density of transportation offer by bus and collective taxis, in relation to the area and the number of inhabitants.

5.2 Demand Indicators

- Reasons and number of daily trips.
- Average mileage per inhabitant.
- Distribution of mobility according to the used modes.
- Ratio of motorized trips (%) carried out by individual transportation.

5.3 Economic Indicators

- Average total cost of a passenger-kilometre, average cost per trip and total cost of person's mobility, per day or year.
- Costs of total annual transportation expenditure according to the actors (households,

communities, etc.) and modes (Private Vehicle, Public Transport, ...).

- Expenditure on personal mobility per person and income category.
- Deficit of urban transport operators in Casablanca and rate of public subsidies for this deficit.
- Prices, and Taxes on transport and fuels.

5.4 Social Indicators (Time, Distance and Costs)

- Levels of service: average speed of travel per mode, travel time per passenger and per zone.
- Accessibility of public transport (mainly buses).
- Motorisation indicators (motorization rate) per zone.
- The indicators characterizing the length of trips by mode with regard to the sociological and economic determinants of households (budgets-distance of all modes or decomposed by mode or by reason).
- The ratio of income spent on urban transport expenditures.
- Social cohesion and travel: social costs.
- Number of bus vehicles assigned to the peripheral areas of the city, in absolute terms, and in relation to the population served,
- Accessibility to major equipment: existence, number and type of public transport offer serving major equipment.
- Accidentology : number of deaths and injuries per year and accident costs.

5.5 Environmental Indicators

- Unit emissions (g / km) of CO₂, CO, NO_x, hydrocarbons and particulates of the various modes considered, gasoline VP, diesel VP, buses, motorized two-wheelers, walking, bicycles.
- Energy consumption per mode in MJ/person.Km, in MJ/Seat.km and in MJ/Vehicle.Km.
- Occupancy rate of vehicle, by passengers.
- Average age of vehicles (PV, Taxis and Buses).

5.6 Governance Indicators

- Clarity and type of transportation governance in the city.
- Number and competence of managers in the different entities governing urban transportation.
- Levels of coordination between the various stakeholders in transportation in Casablanca.

6 APPLICATION, CALCULATION OF SOME INDICATORS AND DISCUSSION

The first indicator of mobility to which we were interested is the fourth offer indicator. We have therefore measured the density of the offer in terms of bus network per area and per inhabitant.

6.1 Offer Indicator: Offer Density

figure 1 shows the density of the offer of the bus network in Casablanca. What comes out is a concentration in the city center comparing to peripheral areas.

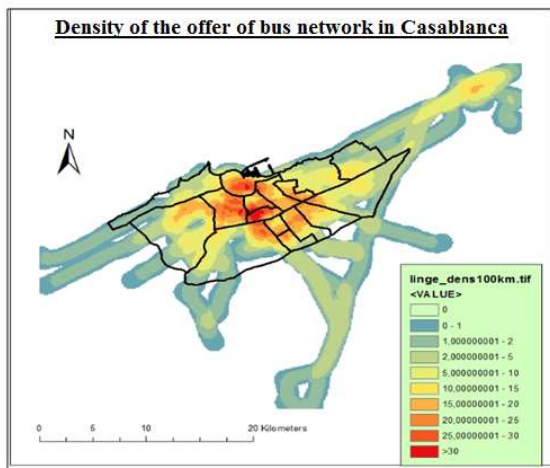


Figure 1: Density Of The Offer Of Bus Network In Casablanca

figure 2 illustrates this concentration in the city center and particularly in the districts of Alfida, Mers-Sultan and Maarif. In fact, a maximum average density of 26km/km² is observed in Alfida as shown in table 1. While the lowest values are recorded in the coastal tourist area of the Anfa district as well as in the peripheral districts which comprise some of the poorest districts of Casablanca.

We note that the transportation offer in terms of Km/km² is very heterogeneous within Casablanca. It varies for example from 1 to 30 between peripheral zones and zones in the center of Casablanca.

6.2 Offer Indicator: Density of Offer (km) Per 10000 Inhabitants

The comparison between the districts of Casablanca, in terms of buses network density in relation to the population, shows the high concentration of the public transport offer related to the inhabitants of the two districts of Assoukhour Assawda and Maarif, while the inhabitants of other

districts of the city are much less served as it is shown in figure 3.

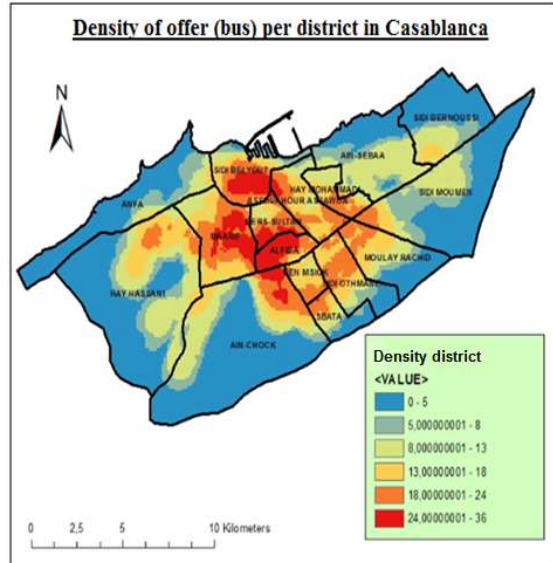


Figure 2: Density Of Offer (Bus) Per District In Casablanca

Table 1: Average Offer Density By District (km/ km²)

| Districts | Average distance (m) | Districts | Average distance (m) |
|----------------|----------------------|--------------------|----------------------|
| Anfa | 4,2 | Sidi othmane | 12,7 |
| Sidi bernoussi | 5,3 | Hay mohammadi | 15,5 |
| Sidi moumen | 5,8 | Ben msick | 16,8 |
| Ain-chock | 5,9 | Sidi belyout | 17,2 |
| Hay hassani | 6,6 | Assoukhour assawda | 17,2 |
| Ain-sebaa | 7,4 | Maarif | 19,4 |
| Moulay rachid | 9,2 | Mers-sultan | 21,4 |
| Sbata | 9,7 | Alfida | 26,0 |

After this, we have been interested in the evolution of the offer between 2004 and 2014. figure 4 illustrates the obtained results.

From the comparison of the maps in figure 4, we can see a decrease in the network density related to the population for several districts: Sidi Barnoussi, Hay mohammadi, Fida, Sbata, Anfa and Sidi Othmane.

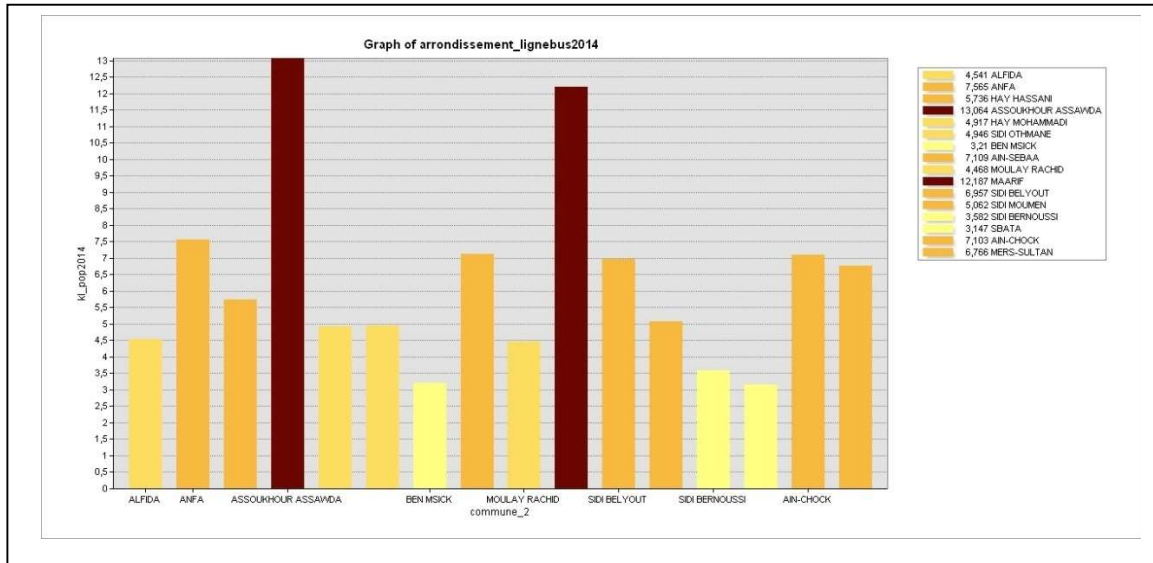


Figure 3: Offer Density Of The Bus Network Per Inhabitants And By District

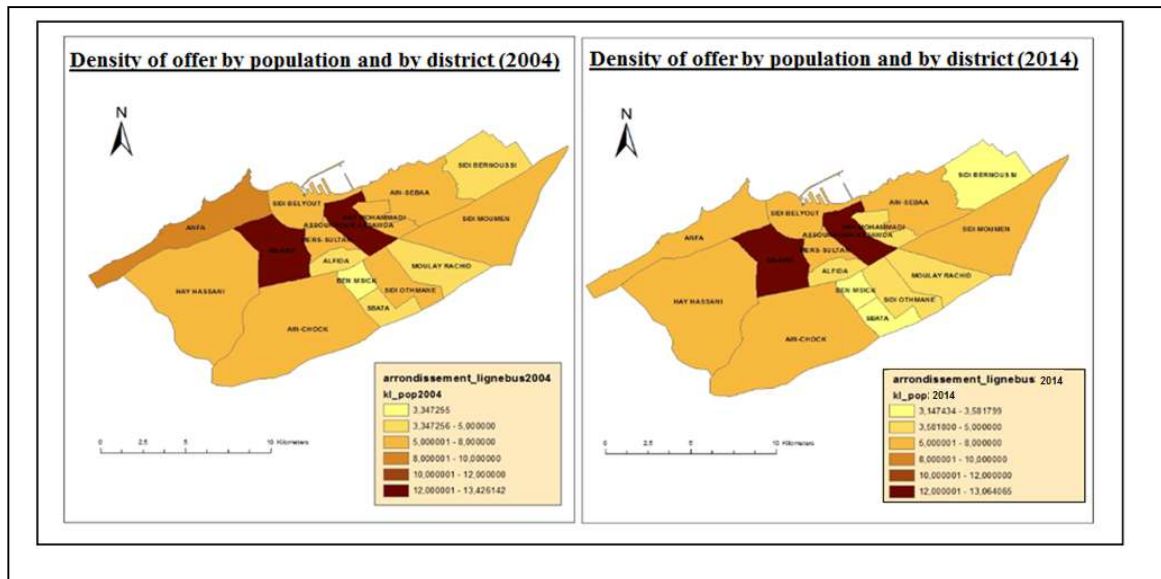


Figure 4: Density Of Offer By Population And By District Between 2004 And 2014

6.3 Social Indicators: The Accessibility of the Public Transport Using Average Distance to the Network or Network Access Time

The study of the accessibility (social indicator) of the network using distance (figure 5, table 2 and figure 6) confirms the heterogeneity of the public transport offer. Access to the bus network is increasingly difficult from the center to the peripheral areas of Casablanca.

The comparison of accessibility between the districts (table 2) shows that the most

disadvantaged neighborhoods (for example: Sidi Moumen, Hay Hassani, Moulay Rachid) record the most difficult accessibility.

The results of this indicator show a non-uniform distribution of public transportation offer in Casablanca.

Indeed, we note a certain inequality of different degrees in terms of public transport offer between the different districts of Casablanca.

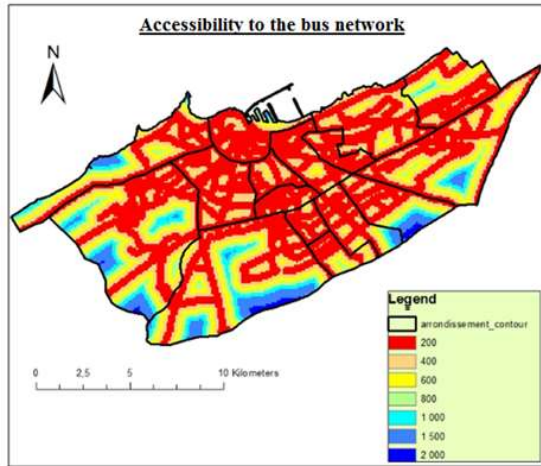


Figure 5: Accessibility To The Bus Network

Table 2: Access To The Network By Average Distance

| Districts | Average distance (m) | Districts | Average distance (m) |
|--------------------|----------------------|----------------|----------------------|
| Alfida | 222,9 | Moulay Rachid | 558,2 |
| Anfa | 484,7 | Maarif | 250,1 |
| Hay Hassani | 517,2 | Sidi Belyout | 321,2 |
| Assoukhour Assawda | 253,8 | Sidi Moumen | 405,8 |
| Hay Mohammadi | 229,8 | Sidi Bernoussi | 358,7 |
| Sidi Othmane | 397,0 | Sbata | 334,8 |
| Ben Msick | 246,2 | Ain-Chock | 567,2 |
| Ain-Sebaa | 294,3 | Mers-Sultan | 259,4 |

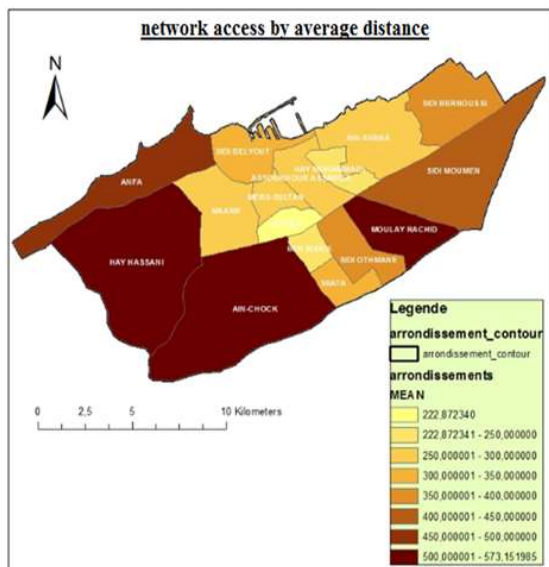


Figure 6: Accessibility To The Network By District

It brought out three weakest districts in terms of public transport offer and accessibility to the network: Moulay Rachid, Ain Chock and Hay Hassani.

6.4 Governance Indicators: Type of Governance and IT Governance

The recent removal of the organizing authority for urban travel (AODU) in Casablanca can only make this transport governance more confused in the long term. Nevertheless, in the short term, this measure has no effect because AODU has never had clear powers or a large budget to do what it has to do.

On another side the use of Information Technology including mapping-based services and web services, facilitate the achievement of Transport authority mission toward the population. “However, citizens’ adoption of e-government services rely on multiple factors, including user awareness and trust” [17]. Indeed, “...awareness IT Governance. is necessary because it has a major influence on the successful implementation of IT Governance within an organization” [18].

Unfortunately, the integration of information technology in urban management and public services in Casablanca remains insufficient, especially for applications addressed to the population. This difficulty also reduces the quality of the coordination between the various stakeholders in transportation in Casablanca.

7 CONCLUSION

Growing mobility, diffuse urbanism and environmental problems have led to the concept of sustainable mobility. The chosen indicators system does not, however, reveal the sustainability of mobility that could be expected. On the contrary, the examples of the calculated indicators show essentially the unsustainability of urban transportation in Casablanca. The use of GIS and Spatial analysis remain a key tool to analyze issues related to urban transport and urban planning generally.

Several questions of different kinds remain to be addressed: how to consider the different environmental aspects and how to integrate sustainability objectives and the political objectives. But the main question is how to link indicator systems to decision-making, especially in

a centralized, confused and non-participatory governance mode.

Nevertheless, this first proposal of indicators will serve to further work towards social change in the direction of the establishment of genuine sustainable mobility.

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