Smart mobility as sustainable mobility: Application to the agglomeration of Fez in Morocco

Mohammed Mouhcine MAAROUFI,
Process and EnvironmentEngineering Laboratory, Faculty of Science and Technology of Mohammedia, Hassan II University of Casablanca, B.P. 146, Mohammedia, Morocco.
mmmaaroufi@gmail.com

Laila STOUR,
Process and EnvironmentEngineering Laboratory, Faculty of Science and Technology of Mohammedia, Hassan II University of Casablanca, B.P. 146, Mohammedia, Morocco.
laila.stour@fstm.ac.ma

Ali AGOUMI,
Civil Engineering, Hydraulics, Environment and Climate Laboratory, Hassania School of Public Works, Casablanca, Morocco.
agoumi.ali@gmail.com

Abstract
To be sustainable, mobility must be smart, safe, fair, and take into account the harmful effects on the environment. It must improve the quality of citizen's life by safeguarding human health and natural ecosystems. This sustainable mobility must optimize resource consumption and public spaces, facilitate accessibility, promote economic dynamism, commit to the social responsibility of individuals, companies, and society, and respect environmental integrity [1]. Thus, sustainable mobility contributes to development and responds to the travel demands of present generations without compromising the ability of future generations to meet their own needs [2]. All modes of transport emitted in Morocco in 2014: 16 million tons of CO2 equivalent representing 19.2% of the country's total emissions. Morocco has set itself a target of 42% for reducing GHG emissions from the year 2030 [3]. This article presents the results of research conducted for the setting up of a new model of sustainable mobility - in a horizon of 20 years – in an urban Moroccan area, booming 'Fez'. It offers a conceptual approach to measuring the sustainability of the transport system. An analysis of the supply and the need for trips in a reference situation first allows for formalizing realistic objectives. Then, a sustainable mobility model is developed to prevent social and environmental costs from being higher than the services provided by the transport systems of this city. Finally, a comparison between the trend situation and the corrected situation with this sustainable mobility model allows us to appreciate its contribution.

Keywords: Accessibility; Collective public transport; Inter-modality; Acoustic pollution; Environment.

1. Introduction
The Process of not mastered urbanization of our cities causes a phenomenon of dispersion of the population and therefore increasing distances. What particularly disadvantage walking and cycling. Socio-economic development causes an increase in disposable income and living standards, as well as two aspects that have a significant influence mobility:

- Increase in individual private motorization;
- Increase in "not compulsory" mobility; that is to say, any displacement whose motive is different from going to work or to study.

These two aspects have a clear multiplier effect on the levels of use of private vehicles compared to collective public transport (CPT). The advantages of the private vehicle, compared to the CPT, are based on better travel conditions such as convenience, freedom of schedules, independence and, in several cases, time saving. However, vehicles represent a set of social expenses linked to the growing needs in infrastructure, to the costs of congestion and pollution, to expenses that society cannot afford indefinitely. This lack of sustainability focuses on the following three factors:

- Costs of infrastructure needed to channel increasing private mobility;
- Costs of gridlocks caused by the lack of capacity at certain times of peak and in some places of the road network;
- Environmental costs.

These aspects, which characterize the current development model, must be avoided in territorial and transport policy because they lack a sustainable vision. This would reconcile social cohesion, economic prosperity and quality of life. This would also ensure sustainability that would prevent the benefits of today from being more serious damage tomorrow.

Indeed, the capacity of road infrastructure cannot keep pace with the growing demand for motorized travel. The priority is to give to "the most sustainable means", CPT, walking and cycling. To this end, three sustainability criteria should be given priority:

- The quality of the public spaces and the urban environment.
- The city's livability: with the aim of improving the quality of life.
- The accessibility: a modal system with a balanced distribution where all people have possibilities of access to the transport system and to the main centers of city activity.

Moroccan cities, currently developing on a continuous increase in motorized mobility and on the construction of road infrastructure, are they "sustainable"?

This article describes the current comprehensive of supply and demand of mobility in the city of Fez. It sets itself realistic objectives to be achieved in order to converge towards sustainable mobility and correct the current trend. Finally, the analysis of the improvement brought about by the measures adopted (in relation to the trend situation without intervention) makes it possible to assess the benefit of the proposed model.

2. Research methods

The main objective of the research that we have carried out in this article is to think of a more sustainable vision of mobility in the urban agglomeration of Fez by applying the following sequence:

Phase 1 - Diagnosis:

- Collect the necessary data covering the following aspects: the configuration of the existing road network (hierarchy, intensities), the CPT system by bus and taxis (occupancy, lines, frequencies) as well as the parking system. Information gathering was focused on the definition of:
    - Socio-economic framework of the urban agglomeration of Fez, in terms of population, economic activity, motorization, education and level of income;

- Territorial and urban framework in terms of road and urban structure as well as the main centers and facilities attracting travel.

- Diagnose the current situation or reference situation of the transport system and analyze the data collected in order to highlight:
  - The main features of the current supply and urban demands travel: structure and size of networks, flows of displacement, modal shares, solicitation networks.
  - The main assets of the current system, which must be preserved.
  - Sectorial analyzes and the main current dysfunctions, located in space-time , were both identified from the point of view of the various users of the city (access to services, availability, regularity, speeds, comfort), and the various operators (territorial coverage, resources, profitability, security, congestion);
  - The main causes associated with these dysfunctions: supply / demand adequacy, complementarity between modes, continuity and homogeneity of networks, coordination of development / transport, institutional framework;
  - The main projects that will affect the urban transport system: infrastructure projects, urban development projects, possible modifications to transport services. These will serve as a basis for valuing the associated demand for future mobility.
  - The trend perspectives of evolution, in terms of sustainability, if no major intervention is undertaken;
  - The main risks and possible opportunities associated with these development prospects.
- Characterize the current socio-economic situation and mobility.
- Analyze on the one hand the impact of current mobility on the network in terms of congestion and on users in terms of accidents and on the other hand the energy, economic and environmental balance associated with the current mobility of Fez.

Phase 2 - Action strategy:

Basing us on the first phase of diagnosis, we have identified and affirmed the agreement establishing the new mobility model include:

- The specific and strategic objectives pursued by the model approach by 2036.
- The main constraints to be observed when developing the action plan.
- The actual room for maneuver and the main levers to be activated.

Establishing the different proposals of the model requires:

- Calibrate a theoretical simulation model, which makes it possible to reproduce the mobility system in a simple and faithful way from the basic variables of territorial development by first carrying out a zoning of the geographical perimeter. The digitization of the network in size Geographies Information System (GIS) is performed on transport modeling software TRANSCAD[1].
- Apply the theoretical model to obtain a prognosis based on current and future mobility needs.

[1] https://www.caliper.com/tcovu.htm

- Develop a plan of action that provides the resources and infrastructure needed to channel mobility in adequate conditions.
- Priories the programs and actions to enable the implementation of sustainable mobility model proposed according to a planned schedule and realistic.

Phase 3 - Validation of the mobility model:

To establish the assessment and quantification of the effects that the new model will have on the Fez city, it was necessary to establish quantifiable objectives that make it possible to detect any successes or failures. A scenario 0, or baseline for 2016, with which future scenarios up to 2036 are compared, has been defined. From this current scenario, all the strategies and actions that make up the target scenario are defined, including the most conflicting aspects, in which it is necessary to intervene. To visualize the expected effects, two scenarios are established:

- Scenario 1: Trend, in which the mobility model is not implemented (evolution without major actions in 2036);
- Scenario 2: Corrected, where the proposals considered in the new mobility model have been deployed in 2036.

3. Results and discussion

3.1. Socio-economic analysis

The socio-economic characterization of the Fez city makes it possible to assess the mobility needs of the population and the means employed. This characterization was based on the data from the 2014 General Population and Housing Census (GPHC) established by the High Commission for Planning.

- Demography: The total population in the study area was 1,336,386 inhabitants in 2014 (4.4 inhabitants/household). The demographic evolution of the Fez city is increasing (19.3% in 10 years) with a slight deceleration, which has taken place during the last decade. The inter-annual average growth rate for the period 2021 - 2026 (medium term) will decrease by 0.75%. That for the period 2026 - 2036 (long term) will decrease by 1.23% [4].
- Motorization level: According to the study carried out by the Ministry of Energy, Mines, Water and the Environment, in Fez, private vehicles represent 71% (109,000) of all registered vehicles, followed by commercial vehicles (those offering a public passenger or goods transport service) with 28% of the total (44,000) and, lastly, motorcycles at 1% of the total (1,450). The average level of motorization of Fez is 82 cars/1000 citizens and 11 motorcycles/1000 citizens. The average age of these cars is 11 years old and 73% of them are diesel cars. The year growth rates of the fleet for the period 2015 - 2030 was estimated on the basis of growth 2005-2015 at 4,2 % [5].
- Income level: the growth rate is positive for the Region of Fez, but remains below the national average. It was estimated at 20,500 MAD against 27,345 MAD for the Moroccan national average [4]. According to the World Bank, Morocco improve its economic growth to 4.2% in 2021, leaving behind him the economic deceleration -6.3% in 2020.

3.2. Territorial and urbanite analysis

- Road structure: The main city roads are composed of main arteries of radial structure as well as semi-circular ring roads transversely connecting parts of the city. The main inter-territorial connection of the city is the A2 toll motorway in the south of the city connecting to the east with Meknes and Rabat and to the west with Oujda. The highway has three exits. In addition, two national roads cross the city: the RN6 between Meknes and Oujda, and the RN8 towards the airport and the city of Ifrane. The connection between the south and the north of the city remains unsatisfactory. Despite the good functioning of these transverse axes in the south of the city, there is no continuity of them in the north. This is accentuated by the railway track, which causes in its surface part a significant cutting effect between the North and the South. The accessibility offered by the structure of the road network makes possible the urbanization of spaces far from the center, leading to an increase in traffic volumes.
- Urban structure: The agglomeration of Fez has experienced in recent decades an influx of population greater than the absorption capacity of the economy caused by the rural exodus. The agglomeration has had to face on the one hand considerable social needs, in particular to absorb unsanitary housing and on the other hand the problem of densification and access to neighborhoods in the north, while the city suffers from 'a spread of urbanization towards the south and the southwest.
- Main centers attracting travel: Although the current level of general urban equipment is not precarious, we see significant differences between areas. The peripheral neighborhoods have a lower endowment in terms of public facilities compared to the central areas or the new structured neighborhoods in the south. The latter benefit from a high level of service, which, in addition, is reinforced thanks to the supply of private facilities [6]. The new Development Plan for the city of Fez is part of a vision of sustainable development, which draws its orientations from the desire to strengthen the status of Fez as a regional capital and consolidate its influence as a cultural capital [7]. The new urban development plan opens approximately 2,700 ha to urbanization, which represents a housing potential of 123,000 units [7].

3.3. Characterization of demand for mobility

Each elderly of more than 5 years makes 2.3 trips per day with an average of 1.1 step movement. 60% travel from Monday to Friday. 71% of trips are daily. 35% of trips last 15 minutes or less, 42% 15-30 min and 6% last more than 60 min. 98% of mobility originates or ends at home.

3.4. Demand modeling

The modeling of mobility demand makes it possible to reproduce the current situation and to measure on the one hand the trend situation according to socio-economic and urban development and on the other hand the situation corrected by the new hierarchy and the development of the road network as well as the implementation of the action plan for the new mobility model. For this, we propose to calibrate a General Mobility Model in four steps:

- Travel generation / attraction model

We want to fit a mathematical model that is able to predict with a certain degree of reliability the number of trips, according to the unit of analysis we are using: the motorized trips of origin and destination of each zone. Transport. The models used will be of the linear type based on the following formulas:

$$O_i = (a * V_i^{\ 1}) + (b * V_i^{\ 2}) + \ldots + (c * V_i^{\ n}) \quad (1)$$
$$D_j = (a * V_j^{\ 1}) + (b * V_j^{\ 2}) + \ldots + (c * V_j^{\ n}) \quad (2)$$

Where
Oi - Number of trips whose origin is zone i;
Dj - Number of trips whose destination is the area;
Vi 1 - Socio-economic variable of zone i; a, b, c - Adjustment parameters (Table 1).
We opted for socioeconomic variables, capable of predicting the future easily from a statistical and functional point of view, such as: population, employment, school places and the number of vehicles.

Table 1. Variables of the displacement generation / attraction model

Model	Variables	values	Statistical T	R^2
Generation (destination vector of the matrix)	Population	0.0119	2.07	0.86
	Vehicles	0.2447	4.45	
	Jobs	0.0752	5.97	
Attraction (origin vector of the matrix)	Jobs	0.1779	7.82	0.86
	School places	0.1054	4.83	

Source: Author own work

- Motorized travel distribution model.

The distribution model allows the reproduction of the number of motorized trips (public + private) between each origin / destination thanks to a mathematical model based on the generation / attraction variables between each transport zone and the generalized cost of the trip between them. The model used will be of the gravitational type based on the following formula:

$$Vij = Oi^{\ a} * Dj^{\ b} * CGij^{\ c} \quad (3)$$

Where
Vij - Number of trips between zones i and j;
Oi - Movements from the starting area i;
Dj - Travel to the finish area j;
CGij - Generalized cost between the two zones i and j ; a, b, c - Adjustment parameters (Table 2). For the generalized cost of travel, we adopted the data from the public and private transport allocation model, examining the time and costs as a function of the demand of these modes.

Table 2. Variables of the displacement distribution model

Variables	Coefficients	Statistical T	R^2
Generation	0.3988	14.37	0.92
Attraction	0.2678	9.70	
Generalized costs	-0.4960	-16.33	

Source: Author own work

- Modal distribution model

To thus reproduce a modal split model that is easily applicable and consistent in relation to the observed reality, we have chosen to estimate two independent models:

PRIVATE TRANSPORT MODEL: This model was estimated using the following linear standard formula:

$$Ratio = (a * R_1) + (b * R_2) + \dots + (c * R_i) \quad (4)$$

Where

Ratio - Variable that determines the non-captive trips made by private transport;
Ri - Variables; a, b, c - Adjustment parameters (Table 3). We used vehicle per inhabitant ratios in the travel origin and destination areas as model variables.

Table 3. Variables of the private transport model.

Model of private transport trip	Variables (vehicle/inhabitant)	Coefficients	Statistical T	R^2
Model of non-captivity	Original ratio	1.7089	13.56	0.74
	Destination ratio	2.3644	17.85	
Accompanying vehicle model.	Original ratio	0.9317	15.64	0.68
	Destination ratio	0.8600	13.75	

Source: Author own work

Public transport model: The objective of the public transport modal split model is to characterize the mathematical formulas that make it possible to reproduce the Taxi-Bus modal choice process. For this, we used aggregated models of the logit type based on the definition of utilities, which depend on the types of transport considered and on the user's choice variables. For an alternative "i", the mathematical expression of the utility is:

$$U_i = K + a * X_1 + b * X_2 \quad (5)$$

Where

K - constant, which collects the part not explained by the variables of the user's choice;
Xi - are the characteristics of choice of the user. These parameters are negative, since they penalize the choice of mode. We estimated the model on the following variables:

- Travel time between origin and destination, adding, in the case of buses, access time, waiting time and travel.
- The cost of the trip such as the kilometer rate for the taxi and the rate for public transport.

Table 4. Variables of the public transport model.

Variables	Codes	Coefficients	Time value
Constant	K	-0.02745	7.5
Travel time	X_1	-0.00234	
Cost of travel	X_2	-0.01881	

Source: Author own work

- Assignment model

The allocation model distributes the demand between the various possible roads of private transport and the lines of public transport. This model was created using the TRANSCAD network simulator, a GIS environment tool.

Network road: The road network includes the road fabric of the city of Fez and the main access roads. To define this road fabric, we had to take into account, fundamentally, two premises:

- Codify the road network according to the needs determined by the adopted zoning.
- Determine the road fabric in order to be able to differentiate the roads from the bus lines.

Each section of the network has the following intrinsic attributes: Point of origin and destination / Length / Typology / Number of ways / Vehicle capacity / lane per hour / Speed (km/h) and travel time (min) under optimal free flow conditions / Volume-time function used to represent the behavior of lanes in traffic jams. The delay functions make the link between the volume of vehicles affected and the travel time for each section. The formula adopted is as follows:

$$T= l\ [t0 + a\ (i / c)b] \qquad (6)$$

Where

T - average travel time in the section (min) ;
l - section length (km) ; t0 - average travel time of 1 km, free flow (min/km);
i - volume or intensity of vehicles (veh/h) ; c - theoretical section capacity (veh/h per track); a, b - adjustment parameters (Table 5)

Table 5. Characteristics of the road network.

Source: Author own work

Type	*Number of ways*	*Capacity (veh/h per track)*	*Speed (km/h)*	*a*	*b*
Expressway	2	2,000	100	2.85	2.90
Main intercity road	2 *	1,800	90	2.85	2.90
Secondary intercity road	1-2	1,600	70	1.10	2.15
Urban artery	1-2	1,600	50	4.60	2.40
Main collector road	1+	1,400	40	4.60	2.40
Secondary collector road	1	1,200	30	2.90	1.89
Local urban route	1-	1,000	20	2.90	1.89
Road link	1+	1,400	50	4.85	2.50
Roundabout	1 *	1,000	20	2.90	1.89

Public transport lines: Fez's public transport network including 51 urban bus lines is defined by the following characteristics:

- Route of the line and stops.
- Service frequency shown as wait time (min) in peak hours.

- Travel rates.
- The real-time running functions of a bus are a function of a series of variables, such as network traffic and congestion. These functions collect the overall behavior of the CPT network as a function of the speeds of the private vehicle and of the characteristic limitations of the buses. We considered the private traffic / public traffic relationship as follows (Table 6):
  - Vprivate ≤ 10 km/h   Vpublic = Vprivate
  - 10 km/h < Vprivé < Vpubmax   Vpublic = a * Vprivé
  - Vpubmax ≤ Vprivate   Vpublic = Vpubmax = 80 km/h

Table 6. Values of public transport time functions

Code	*Type*	*Function*
1	Main urban road	Vpub = 0.5720 * Vpriv
2	Secondary urban route	Vpub = 0.5473 * Vpriv
3	Expressway	Vpub = 0.6670 * Vpriv
4	Toll highway	Vpub = 0.6670 * Vpriv
5	National road	Vpub = 0.5765 * Vpriv
6	Road connections	Vpub = 1 * Vpriv

Source: Author own work

3.5. New model of sustainable mobility

The mobility plan must define the guiding actions to consolidate a city model, which finds the balance between the productive system / economic activity / urbanization, and territorial mobility needs. Starting from the principles of environmental, social and economic sustainability. The ultimate goal is to have a more welcoming, human, inclusive, healthy, dynamic and resilient city.

The mobility management model that we propose is a management model by 30 zones or calm traffic zones (Fig. 1). Zones 30 are environmental zones of multifunctional homogeneity, from 400 to 500 m. Within these areas, the dominant modes are pedestrian and cycling. The streets can receive car traffic, but with a maximum speed of 30 km/h.

This management model aims to slow down, prevent and reverse the trend of the current mobility model, based on the private motorized vehicle, to create a more habitable public space and traffic calming zones. Public space inside neighborhoods must be used for meeting and communicating with citizens.

Taking into account the objectives and principles mentioned above, a new urban mobility model reflecting the action plan has been defined below:

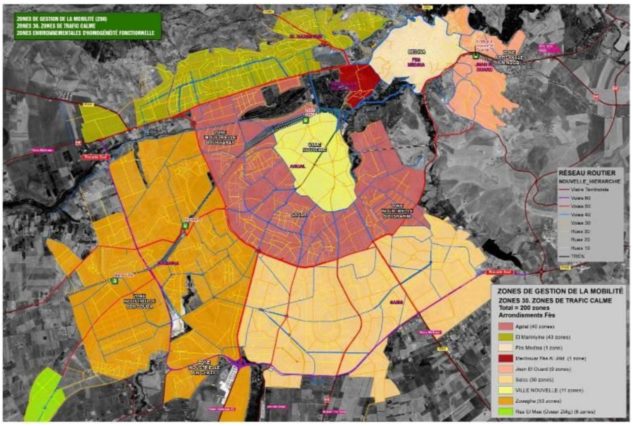

Fig. 1. Calm traffic management zone of the new sustainable mobility model

3.6. Periodization of the mobility model plan.

An action plan made up of 10 programs divided into 70 actions has been drawn up. In order to assess the appropriateness of the various measures proposed according to a vision of sustainable mobility, the following 10 assessment criteria were used:

- Sustainability: social / environmental / economic.
- Quality of life: habitability / urban environment / accessibility.
- Road safety: accidents / congestion.
- Awareness: follow-up / involvement / collaboration / participation.
- Ability to solve problems.
- Ability to respond to demand.
- Complementarity between the different modes: inter-modality.
- Conditions of implementation: organization / technical feasibility.
- Financial costs associated with investments, operation and operation.
- Economic costs for users and operators.

The values considered for the multi-criteria evaluation are 0-1-2-3. Where 0 represents a zero impact and 3 a maximum evaluation compared to the evaluated parameter. Negative values refer to the difficulty in implementing the proposed measure. The total evaluation implies the priority, the appropriateness or the ease of implementation of each action / program (Fig. 2 & 3).

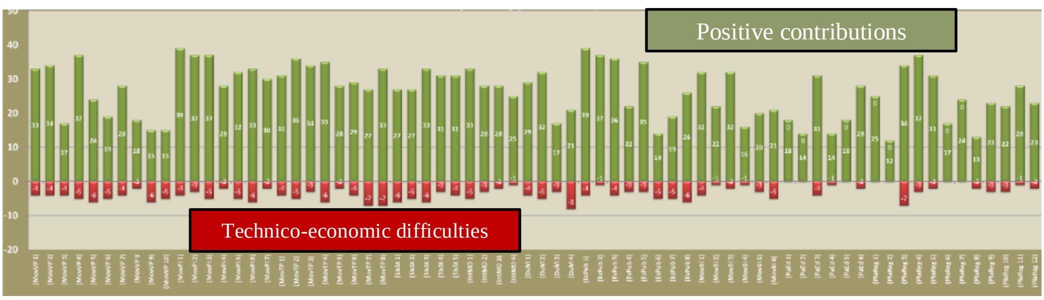

Fig. 2. Action Plan: Assessment of positive contribution / difficulty in implementing actions.

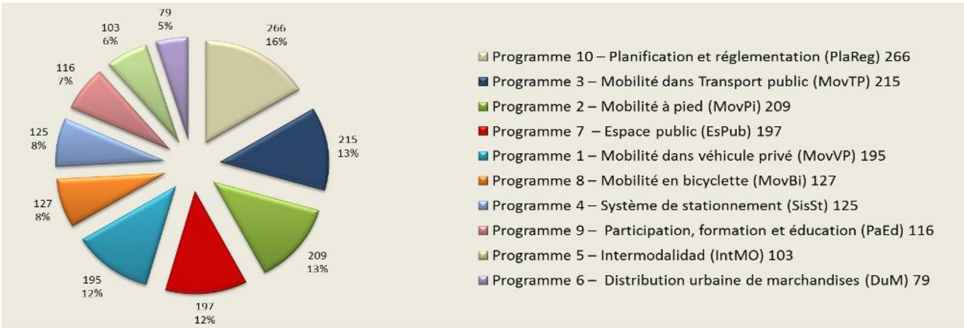

Fig. 3. Action Plan: Priority of programs.

3.7. Impacts of current, tendency and corrected mobility

To qualify and quantify the expected effects of the new model of mobility, three scenarios are established:

- Scenario 0: Current mobility (baseline situation in 2016);
- Scenario 1: Trend, in which the mobility model is not implemented (evolution without major actions in 2036);
- Scenario 2: Corrected, where the proposals considered in the new mobility model have been deployed in 2036.

It make possible to assess the contribution or otherwise of the new model through indicators related to safety, quality of life and the following environmental consequences:

- Congestion and points of conflict: we visualize positive evolution of 29 conflicting points and 14 road sections with a very high concentration of congestion in the city of Fez (Fig. 4, 5 & 6) [8]. The reduction of the level of risk of accidents is associated with a trend downward vehicular intensity resulting from the implementation of sustainable mobility plan.

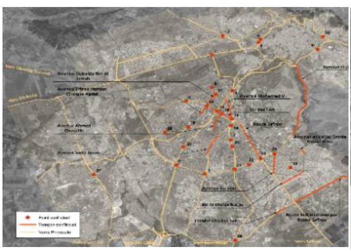

Fig. 4. Conflicting points and high congestion sections (Scenario 0).

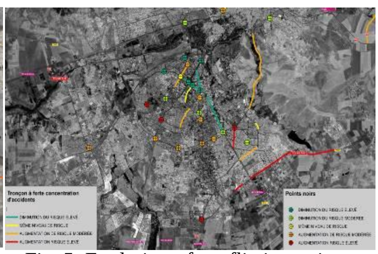

Fig. 5. Evolution of conflicting points and high congestion sections (Scenario 1).

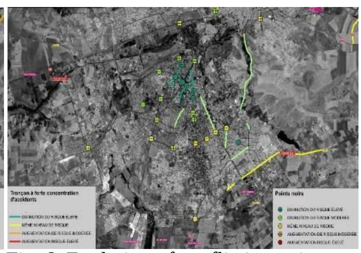

Fig. 6. Evolution of conflicting points and high congestion sections (Scenario 2).

- Acoustic pollution: Regarding the noise evaluation, we carried out a theoretical model considering that the sound level equivalent to one hour (Laeq, 1h) increases logarithmically with the increase in the Average Daily Intensity (ADI) of the vehicles [9]. From this theoretical model, we can conclude that just over 17% of the urban area of the city of Fez suffers from episodes of noise pollution capable of causing some type of discomfort in people (Fig. 7). This environment risk is focused in the central urban area of the city where the traffic intensities, considered the main sources of noise in the city, are the highest and most concentrated. The model allows us to see that over 31% of the urban area will undergo a risk of noise pollution in the case of a scenario trend on the horizon in 2036 (Fig. 8). The new model will reduce over 45% urban area undergoing a risk of medium and high noise (Fig. 9).

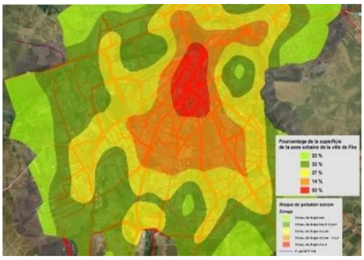

Fig. 7. Theoretical model for actual acoustic pollution (Scenario 0).

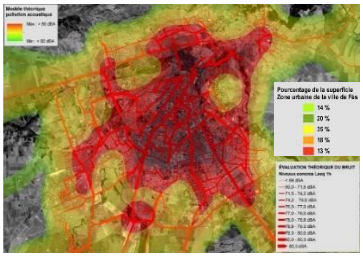

Fig. 8. Trend of acoustic pollution (Scenario 1).

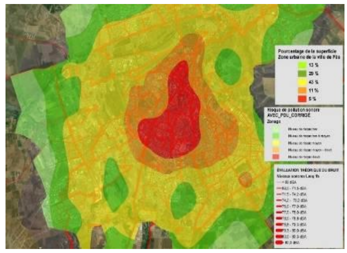

Fig. 9. Assessment of acoustic pollution (Scenario 2).

- Energy, economic and environmental balance: In order to estimate the city's energy balance, we consider the fleet according to the distribution in the chapter characterization of motorization with the distances considered in the Origin/Destination matrix and we take the average consumption of each type of vehicle. The energy total consumed annually by the Fez motorized transport system is 57,000 Tep. The annual energy cost is 643 Million MAD. The annual contribution of the road mobility system to global warming amounts to 173,500 tons of CO2. The calculations impact of tne new model confirm a saving 300,000 tons of equivalent CO2 until 2036. The savings from fuel consumption will be 123.9 million liters, or 1.1 Million MAD (10 % of the overall cost of implementing the sustainable mobility plan).
- Air pollution and GHG pollution: To analyze the levels of theoretical concentration current of air pollutants and those trend, we adopted a simulation model of statistical distribution depending on the distance to the measurement point. This distribution reveals that the highest values are found in the urban center where higher concentrations of motorized traffic are generated every day (Fig. 10 & 13) [10]. The trend concentrations at 2036 horizon will be increased by more than 70 % compared to those in 2016 (Fig. 11 & 14). The new model will reduce over 25% emission pollutants (Fig. 12 & 15).

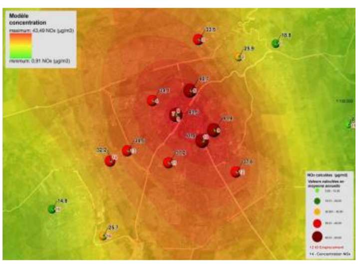

Fig. 10. Current NOx concentrations (µg/m3) (Scenario 0).

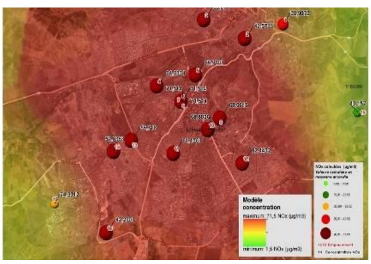

Fig. 11. Trend of NOx concentrations (µg/m3) (Scenario 1).

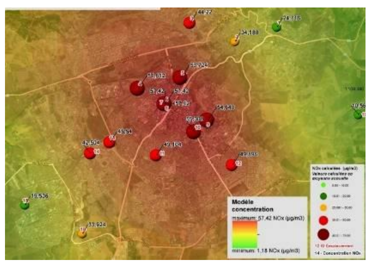

Fig. 12. Assessment of NOx concentrations (µg/m3) (Scenario 2).

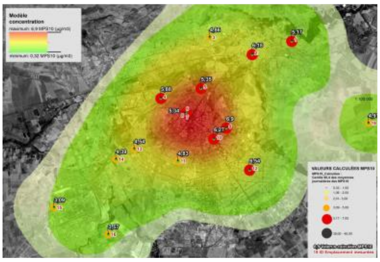

Fig. 13. Current MPS10 concentrations (µg/m3) (Scenario 0).

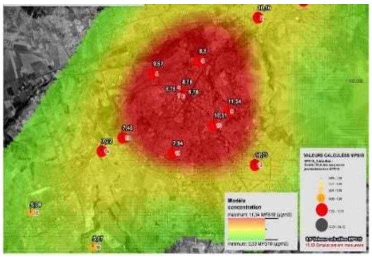

Fig. 14. Trend of MPS10 concentrations (µg/m3) (Scenario 1).

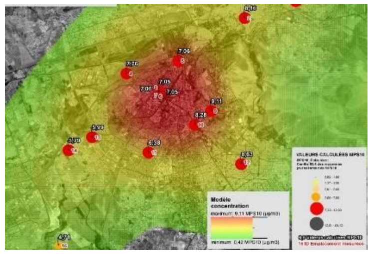

Fig. 15. Assessment of MPS10 concentrations (µg/m3) (Scenario 2).

3.8 Mobility contribution of the proposed model

In order to assess the mobility effects of the new sustainable model and in what proportion they contribute to the achievement of the objectives above defined, the simulation of the model by introducing the adopted measures makes it possible to visualize the different indicators:

- Travel by car: The number of trips by car (private vehicle + taxi) will be reduced with a sustainable mobility plan by 19.6% (Fig. 16). The average speed of the trend scenario of 24 km/h will increase by 21%. Total véhicules.kilomètres (veh.Private + taxi) will decrease by 18%.
- Travel by CPT: The number of CPT trips will increase by 63.8%. The total of vehicle.kilometers of CPT will increase by 12% and that of passenger.kilometers of CPT by 73% (Fig. 17). The modal share of CPT will increase to 34% with the application of the sustainable mobility model against 20% for the trend scenario, a when the share of private cars will be reduced to 42% against 52% without corrective measures.

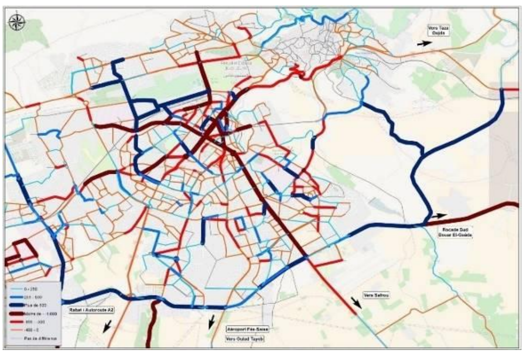

Fig. 16. Difference of IDA With / Without sustainable mobility plan in 2036.

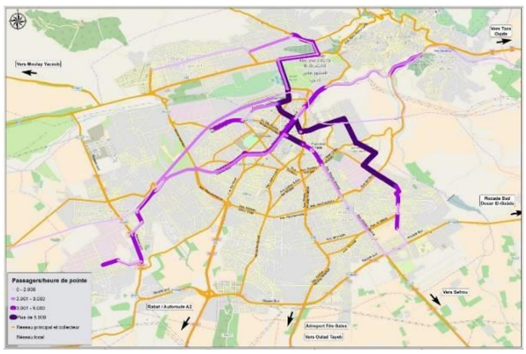

Fig. 17. Difference With / Without a sustainable mobility for passengers for CPT network in 2036.

Source: Prepared by the authors using data from [11].

Accessibility: Currently, the percentage of the area covered by the CPT network for a time interval of less than 3 minutes is 22% and 23% between 3 and 5 minutes. This percentage increases for longer intervals at 39% for 5-10 minutes, and 17% for 10-20 minutes (Fig.

18). The new model will increase area covered by the network for a time interval of less than 5 minutes (less than 400 m) at 85% (Fig. 19).

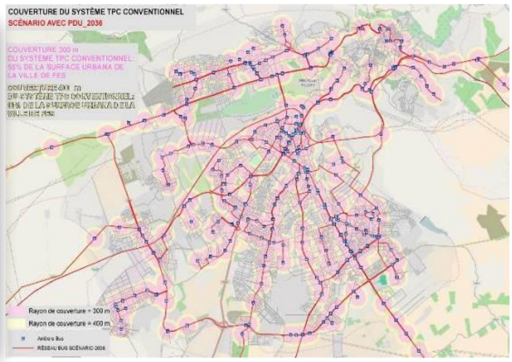

Fig. 18. Current coverage zones on foot of the Bus network / location of the stops (Scenario 0).

Fig. 19. Coverage zones on foot of the Bus network and location of the stops (Scenario 2).

Source: Prepared by the authors using data from [11].

4. Conclusion

The detailed analysis of the socio-economic, territorial-mobility, infrastructure, environment, and the characterization of current trips at the level of the city of Fez have made it possible to distinguish the main dysfunctions to be corrected in order to migrate to smarter and more sustainable mobility.

The approach of a more sustainable mobility model and a livable public space for the city of Fez requires a set of technical, organizational, normative, educational, participatory and economic instruments for its development. This model establishes a new hierarchy in the city's road network, adaptation to urban morphology and the distribution of public space from an integrated vision of mobility planning and space management public.

The improvement of accessibility as well as the revitalization of urban functions in the city center and traditional / historic urban areas such as the Medina, will create proximity between the origins and destinations of travel and respect strategies on sustainable mobility following:

- Stimulate livability in residential areas (in balance with equipment and commercial uses) by creating a local road network and reducing the demand for motorized travel, in particular private vehicles, and promoting the use of modes soft and medium CPT.
- Ensure that the physical and geometric conditions of the road network are more functional (access to the road network, road distribution, parking conditions) are more secure and that the traffic regulation conditions are smarter.
- Use parking regulation mechanisms to deter inappropriate automobile use. These mechanisms will apply different levels of restriction (priority for residents, regulation of service movements and generation of modal transfers to CPT modes for working journeys). Gradually replace free parking on public roads in the most fragile and problematic areas of the city, the center and neighborhoods to promote

parking for residents. An action that must be accompanied by a functional review of the public space.
- Stimulate the use and urban design of public spaces receiving new transport exchange poles as revitalizing elements and generators of productive urban activity.

The sensitivity analysis of the various theoretical models shows that the variations between the results of these models and the actual development of the situation between 2016 and 2020 vary between -10% and + 10%, which concludes that there is a good prediction capacity. The model could be better calibrated by detailed household surveys and Origin / Destination surveys.

References

[1] "Directorate General for Sustainable Mobility Policy and Electrification of Quebec Sustainable mobility policy 2030," p. 54 p, 2018.

[2] "Office for the Coordination of Sustainable Development of Quebec: Quebec indicators of sustainable development," *Summary document*, p. 10, 2010.

[3] "Ministry of Energy, Mines and Environment: Second updated Biennial Report of Morocco within the framework of the UNFCCC," p. 212, 2019.

[4] "High Commission for Planning: General population and housing census.," p. 189, 2014.

[5] "Ministry of Equipment, Transport, Logistics and Water: METLE 2018 in figures," p. 36, 2019.

[6] "Ministry of the Interior: Regional land use planning plan for the region of Fez Meknes," p. 202, 2017.

[7] "Fez Urban Agency: Urban development plan," 2018.

[8] "Ministry of Equipment, Transport, Logistics and Water: METLE 2014 in figures," p. 36, 2015.

[9] "French Ministry of the Environment and the French Living Environment - Ministry of Transport: Guide to noise from land transport," p. 90, 1978.

[10] "Department of Surveillance and Risk Prevention: The cadastre of atmospheric emissions in the Fez region," p. 54, 2015.

[11] "Urban Commune of Fez: Monograph of the urban agglomeration of Fez," p. 102, 2015.