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Mobility and Risk Interaction: Vulnerability of Accessibility of the Algiers Metropolis

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ABSTRACT

This article emphasizes on the analysis of the vulnerability of people physical infrastructures' mobility at a territorial level, in an area with a radius of 200Km around Algiers site. After defining the terminology used, the methodology has been detailed in four parts. The first part is devoted to the understanding of people's daily transportations, and the infrastructural chain of transport system in the capital of Algiers. This part allows us to identify and localize, in a second part, the key-infrastructures, major pieces of roads networks and transport. In the third part, these key-infrastructures vulnerabilities were evaluated, which predispose them to damages and failures. The objective of the third part was to understand risks involved by the entire areas studied, including the possible reduction in the accessibility of different spaces due to operational loss of key-infrastructures. Different scenarios have been envisaged, placing into perspective the predictable spatial repercussions, at the capital's level. The results are expressed by maps and time access curves for several types of issues (between different urban areas, and access to major medical infrastructures of Algiers).

Key words : *Road networks, Urban vulnerability, Access, Earthquake, Modelling, Algiers.*

Introduction

Without pretension to redefine the concept of risk, we can consider that it expresses the possibility to lose what we consider important. Further, the search approach that simply consists on asking about "what is important" in first, then, trying to understand why and how we "risk losing it" seems making sense However, "the possibility of losing" assimilates simultaneously notions of both hazards and vulnerability (Pascale Metzger, Robert d'Ercole, 2015).

The vulnerability factors analysis provides a means for predicting potential prejudice amplitude. As for, it supplies a quantitative measure of the elements exposure, and capacity's response qualitative measure of a group or individual, exposed to a disaster. In fact, the response quality of a stricken group or individual modifies the vulnerability. (Jean-Claude Thouret, Robert d'Ercole, 2015).

In recent decades, there have been an increasing number of natural disasters affecting people and property. The authorities' response has been reflected in practice by the implementation of constantly evolving risk prevention and management systems since 1980, resulting in tools and acronyms abundance that thwart their appropriation by all stakeholders (Alain Feretti, 2015).

In general, the world is challenged by the scale of human, economic and environmental damages

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caused by natural and industrial disasters in different regions: Armenia, Indonesia, Turkey, Afghanistan, India, China, Vietnam, South Korea, Morocco, as well as by the three (03) major devastating disasters that accrued in Algeria during the previous years, in particular the floods of Bab El Oued in 2001, the earthquake of Boumerdes in 2003, and finally, the gas accident of Skikda in 2004. Today, through the development of information resources that inform us almost instantaneously about catastrophes which occur in the globe points, events number that we become aware of is increasing, and is generating a sense of increased vulnerability of our society to disasters (Gana Fayssal, 2011).

The rapid, functional, and demographic transformations that coincided with the restoration of the city of Algiers, being the national capital in 1962, had the effect of creating an unprecedented urban growth. These transformations led to the creation of a dynamic which would have occurred a global and profound change in the city structure, and the expansion of its urban mass by its extension in various directions. In fact, this growth is the result of the urban policy adopted by public authorities since the first decade after the independence, with the objective of developing the capital in order to become a major centre of the country (Hadjiedj, Ali, 1997).

Algeria is faced with a complex problem, which is the spatial repercussion of a rapidly growing population. The pressure exerted on the coastal strip, more particularly on the part where Algiers is located, is worrying. Algiers gigantism and the consequences of an already fragmented urbanization spread, over the entire Mitidja plain, only confirm this trend towards the coastal urbanization, which continues to intensify with the newcomers' arrival from the surrounding wilayas (Mohamed Chadli *et al.*, 2012).

Today, 91% of the Algerian population lives along the Mediterranean coast, on 12% of the country total surface area, and almost half of the population is urban. The urbanization is in a continuous propagation despite of the government efforts to reduce the demographic saturation on coastal cities. Algiers, in particular, is under a human pressure with a population of 3 million inhabitants according to the Algerian Statistical Office (BERRAH, 2015), and up to 7,7 millions according to certain non-governmental organizations (POPULATION DATA, 2015). It is the central core of the economy and business in Algeria (Walid RABEHI *et al.*, 2018).

This article emphasizes on the analysis of the vulnerability of people physical infrastructures' mobility at a territorial level, in an area with a radius of 200Km around Algiers site, with a population of about three million inhabitants. After defining the terminology used, the methodology has been detailed in four parts. The first part is devoted to the understanding of people's daily transportations, and the infrastructural mesh of transport system in the capital of Algiers. This part allows us to identify and localize, in a second part, the key-infrastructures, major pieces of roads networks and transport. In the third part, these key-infrastructures vulnerabilities were evaluated, which predispose them to damages and failures. The objective of the third part was to understand risks involved by the entire areas studied, including the possible reduction in the accessibility of different spaces due to operational loss of key-infrastructures. The results are expressed by maps and time access curves for several types of issues (between different agglomerations, and access to major health infrastructures of Algiers).

Apprehend the risk through vulnerability

Naturalist for a long time, French geography was first devoted to the hazards analysis, before becoming entrenched in social sciences. Thus, risk management has long been focused on the hazard control, and in recent decades, hazard knowledge considerably progresses: phenomena are identified, measured, modelled, historically reframed, updated and mapped. Then, "until the end of the 1980s, so-called "natural" risk maps generally only included a topographical background on which were superimposed the zones exposed to a specific phenomena type (flood, landslide, avalanche corridor, etc.) ", i.e. hazard zoning (F Renard, D Soto, 2015).

The intrinsic ambiguity of risk concept makes it difficult to pin out, both ontologically and epistemologically. Indeed, from an ontological point of view, its grasp is complex given that risk« does not exist », that it is always potential and virtual: when a risk materializes, it is no longer a risk, but, a disaster. Therefore, risk is never « current ».From an epistemological point of view; it is hardly easier to circumscribe it, insofar as knowledge about risk is "knowledge about non-knowledge" (Céline Kermisch, 2020).

Nowadays geography gives prominence to risks issue, while it had been long interested in nature: it's functioning and the relationship that societies have

with it. For the geographer, risk is a social object that must be distinguished from hazard, a physical process. It is only perceived and experienced as dangerous that the hazard becomes risk.

A distinctionmust also be made between risk and disaster: unlike disaster, risk is probable but not realized (Yvette and Magali-Reghezza, 2005).Vulnerability concept, informing us about poverty process, represents a major importance in poverty and its dynamic analysis, since it allows us to adopt a preventive vision of the later. Generally defined as the probability of seeing their well-being level deterioration as a result to a shock, vulnerability reflects external pressures to which individuals are subjected. However, the laterare not deprived of all reaction capacity, as the resilience concept emphasizes (Claire Gondard-Delcroix and Sophie Rousseau, 2004).

From transport networks vulnerability into vulnerability of accessibility

A transport network vulnerability notion focuses on possible impacts associated with network efficiency losses, built by possibilities which space offers (Martin Tanguy, Aldo Napoli, 2016). In the broad sense, transport network defined all the, techniques, means, and processes allowing people and goods transport, from a place to another in a geographical area. Therefore, transport networks grant the linking between the different places of a territory and entities occupying them. Following a specific geographical organization, they structure and develop a space into a chain made up of traffic axes. For this reason, networks represent a major input in the study of a territory, its functioning and evolution.

The road networks vulnerability can be analyzed retrospectively or presumptively, in several forms: road infrastructure physical (material) vulnerability, road network functional vulnerability, territorial vulnerability linked to roads' access of different vital issues related by these road networks (populations, economic activities, rescue centers...) (Frédéric Leone *et al.*, 2014).

From the risk notion into the more elaborated structural vulnerability of transport networks, does exist a world of definitions, concepts, and approaches that we have sought. In fact, we have defined the notion relating to risk, and identified promising research directions in geography filed. Thus, networks fragility is tangible from the elementary level of their constituents into their operation and the benefits they generate, directly or indirectly.

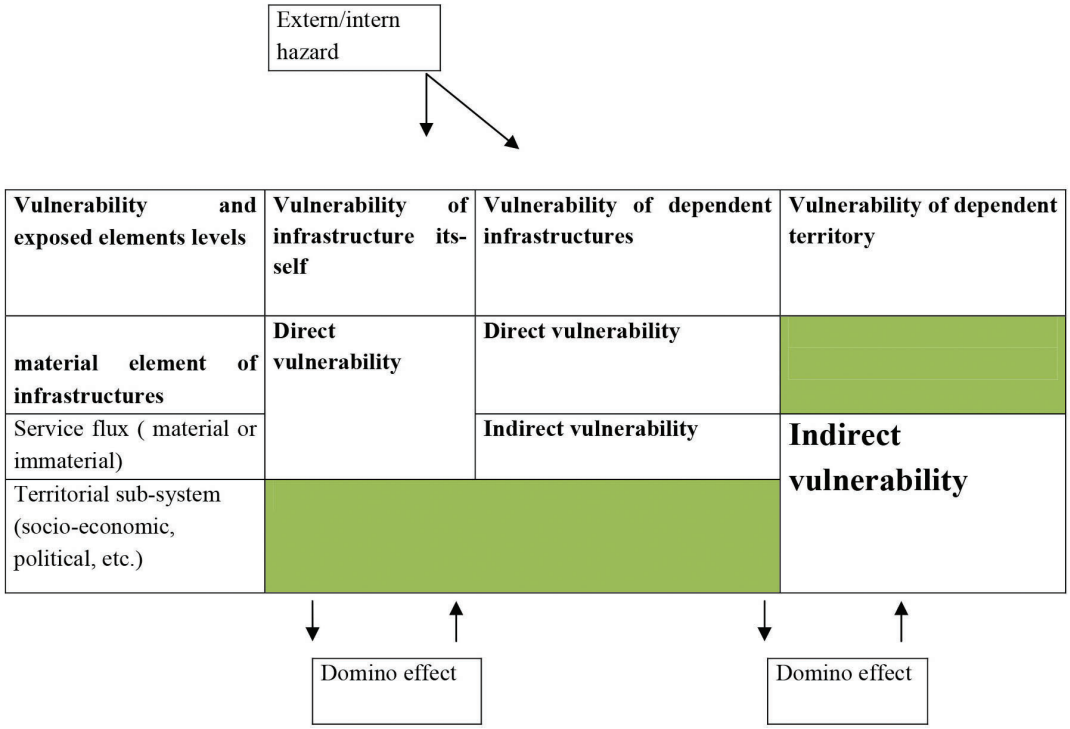


Fig. 1. Vulnerability levels (UTASSE Marina, 2015)

Actually, there is no consensus relative to the meaning given to transport network vulnerability, and certainly not to its appreciation (Jean-Francois Gleyze, 2005).

Through these definitions, it is clear that the impacts do not only concern the infrastructure damage, but also affect the use function provided by this network. Consequently, network damage modes can be prioritized in the form of direct or indirect damages, and can be tangibly or intangibly measured. From the impact to infrastructures into the functional and territorial consequences generated by these impacts. Accordingly, two levels of vulnerability can be analyzed.

As shown in Figure 1, the two levels of vulnerability are:

Direct vulnerability : Is in the core of prevention concerns. It is defined on the basis of constructions occupying a given territory, described in spatial (position) and functional (for residential use, institutions receiving public, etc.) terms. For phenomena involving human lives, vulnerability must also be described in terms ofdensity, and occupation type (COS, seasonal and annual occupation, etc.) (Yannick Manche, 2006).

Indirect: This vulnerability is by far the most difficult to take into account. However, it is essential in order to gasp all phenomena. It is these indirect effects that are the most costly, economically and socially. These effects can lead to the territory desertification. Until now, this vulnerability type has rarely been taken into account in the subject's different researches. The problem arises in the same way as for impact studies: the task scale, at the study area, prevents a more global vision(which in any case, is politically undesirable) (Yannick Manche, 1997)

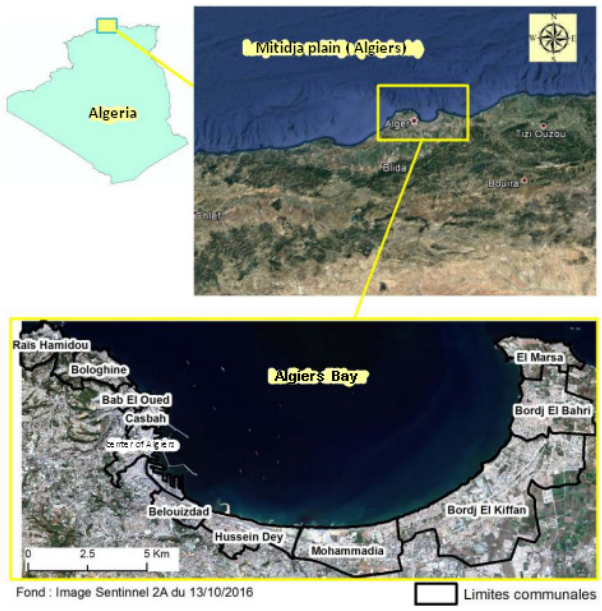


Fig. 2. Study area: Bay of Algiers communes (Walid Rabehi *et al.*,)

Results and Discussion

The study area

Algiers metropolis is home to more than 5,3 million inhabitants (2018), nearly two thirds live in the wilaya of Algiers. It represents the first pole of non-hydrocarbon economic activity in the country, and it is the pole of command functions (government, main companies head offices). Its strategic importance justifies a higher level of equipment than other parts of the county, but makes the need for effective prevention to deal with natural risks all the more important. Lands use in the wilaya of Algiers is characterized by coastal urbanization which extends over the reliefs of the Sahel and in the eastern plain of Mitidja, vast agricultural areas in southern and western plain of Mitidja, forest areas on limited surfaces (Bainem forest, Zeralda forest), two wetlands (Reghaia and Mazafran). It emerges from this analysis that more than 40% of the Wilaya of Algiers area was urbanized in 2012. The entire coastline of Algiers's bay is now continuously urbanized.The urban extensions extend over the Tell massif to the west and south of Algiers, and gradually join the Mitidja plain to the south. To the east, the Mitidja plain is largely mitigated by urbanization supported by the establishment of large areas of economic activity, generating employment, and requiring the proximity of housing areas for employees (Egis Eau / IAU-IDF / BRGM, 2013).

Algiers: vulnerable territory and multiple issues

Vulnerable territory to earthquake

Algiers, the capital city, the House of State and Algerian central institutions, the country's largest urban area, the gateway to the Mediterranean and the world, is subject to natural risks that can hinder its functioning and condition its development. Through the following lines, we have tried to synthesize the capital vulnerability to natural risks (in our case earthquakes and floods).

Algiers region is in the Mediterranean geo-dynamic context, resulting from the collision of the African and Eurasian plates. The Tellian Atlas, to which the study belongs, is made up of a significant mountainous relief. It is characterized by a great geological complexity along the Mediterranean coast and, is the result of a long multiphase geo-dynamic history.

Seismic activity mainly localized in geological formations of Mio-Plio Quaternary ages, the region of Algiers has experienced several powerful earthquakes in the past. Its seismic activity is almost permanent and is differentiated according to two periods of 1365 – 1716 and from 1910 to the present day. (Djeddi Mabrouk, 2013).

The seismic activity of the Algiers region is mainly located in Neogene Mitidjabasin (Fig. 3). In this region, major earthquakes have occurred throughout history, causing sometimes the death of thousands people. It is particularly the case of the 1365 and 1716 earthquakes, and Blida earthquake in 1825. Studies carried out in the Mitidja basin show that the active tectonics are manifested along the northern and southern edges of the basin by numerous faults and folds with opposite game in a NE – SW direction (Sahel fold-fault), intersected by combined accidents in a NW – SE direction, which little by little deform these slopes and elevate the coastal region. There are three zones: 1- **The western region of Algiers**, this region, where the earthquakes of October 29, 1989 (Ms: 6.0) and September 4, 1996 (Ms: 5.7) occurred, is marked by the Sahel anticline presence, a major structure of nearly 60 km long and oriented NE – SW. 2- **The southern region of Algiers**, this region is marked by the faultschaplet that border the area of contact between the Mitidja basin and the Blida massif. This border shows signs of tectonic deformations affecting the Plio-quaternary levels. 3- **The eastern region of Algiers**, the recent Boumerdes earthquake of May 21, 2003 (Mw: 6.8) is the expression of the sometimes significant seismicity which manifests itself in this region. This earthquake allows highlighting, for the first time, the activity of the Zemmouri marine fault [46], nearly 50 km long, located between Dellys and Boudouaou el Bahri and in a NE – SW direction (F6 fault) (Abdel Krim Yelles-Chaouche *et al.*, 2005).

The city of Algiers suffered the damage of the 2003 Boumerdes earthquake in its eastern part, but centre of Algiers has been exposed to more disastrous earthquakes since 1716. This date earthquakeis so ancient that there is not enough information to give a scenario based on this earthquake. Consequently, it is decided that the modelling of a scenario earthquake in Algiers will be done on the basis of active faults (method-2). Figure 3 shows the locations and inferred surface traces of active faults in Algiers and its surroundings. The faults of Blida, Sahel and Thenia are onshore faults and their locations have been studied by geologists. The Khair al Din and Zemmourifaults were found in recent investigations on the ocean floor.

If urban growth, in a place subject to seismic risk, is accompanied by building standards, and if urban planning takes the risk into account, then, the disaster can be avoided and the situation can be better managed and even reduced. However, this is not always the case. Algiers, like Algerian cities, has experienced a great urbanization movement. From the medina to the metropolis, and from the collected fortress it is transformed into a fragmented city, subject to degrees of vulnerability. However, after independence, we are witnessing a vast urban sprawl, neglecting the precautions which would have been necessary to face seismic risks because of the urgency of the need to find land to build facilities and housing for an ever-increasing surplus of population.

Table 2 shows the seismic hazard omnipresence, as a result of which the triggering of such phenomenon, on a large scale and with a high magnitude,

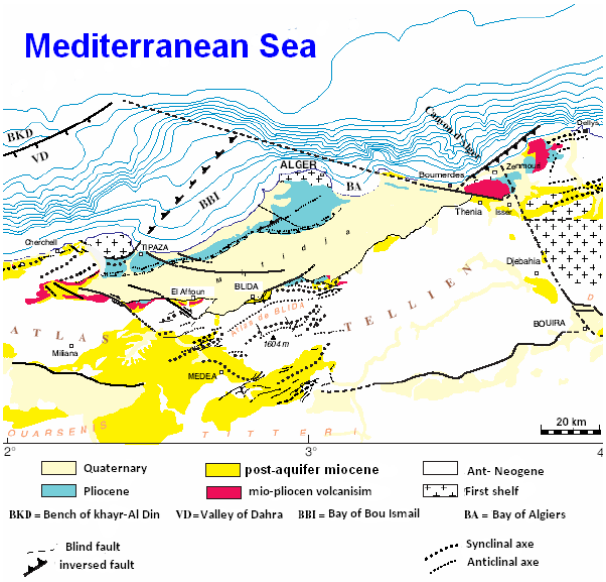


Fig. 3. Schematic map of active faults for the Algiers region (Boughazi Khadidja, 2012)

Table 2. Seismic capacity (MCE magnitude) of regional active faults

Faults	Length (km)	Descent angle (°)	Depth (km)	Rupture surface (km²)	Mw	Mw for 475 year return period
Sahel fault	75 ± 10	45	15	1590 ± 210	7.2 ± 0.3	5.9 ± 0.3
Chenoua fault	50 ± 10	45	15	1060 ± 210	7.0 ± 0.3	5.8 ± 0.3
Blida fault	90 ± 10	45	20	2545 ± 280	7.4 ± 0.3	6.8 ± 0.2
Khair al Din fault	100 ± 20	45	20	2830 ± 565	7.4 ± 0.3	6.8 ± 0.2
Zemmouri fault	100 ± 20	45	20	2830 ± 565	7.4 ± 0.3	7.0 ± 0.1
Thenia fault	40 ± 10	45	15	600 ± 150	6.8 ± 0.3	5.9 ± 0.2

(Source: CHLEF 2005)

would carve up the main decision-making centers and leave Algeria without power and command, since the majority of institutions would be devastated by the disaster.

The major issues of Algiers

A spectacularly growing population characterised by high densities

Totalling in 1830 an estimated population of 30,000 inhabitants, mainly located in the Casbah, Algiers in 1921 had 190,000 in habitants and its periphery a little more than 40,000. The census of 1936 indicates a population of 367,000 inhabitants, 103 of whom. These few elements indicate a perceptible dynamism from the thirties in the periphery close to Algiers (Nait Amara, 2012).

From 1830 to 1962, Algiers population multiplied and experienced continuous growth. The last two colonisation decades were particularly marked by important migratory movements, which disrupted its population. The urban extensions in this period gave Algiers its modern form as a large city (HAMMACHE, 2003).

The Algerian population grew unbridled and rapidly after independence. In fact, according to the various population censuses, Algiers went from 994 751 inhabitants in 1966, 1 587 898 in 1977) to 2 128 419 in 1987, 2 562 428 in 1998 (+1.66%/year), 2 947 461 in 2008 (+1. However, the growth rate, which was very rapid in the 1970s, has tended to decline since the 1980s, with the rural exodus almost complete, and a fall in fertility rates confirming the second phase of the demographic transition that began in the 1980s.

Urban densities are concentrated along the Bay of Algiers, with higher densities in the Casbah, the historic center and around Hussein Dey. However, a densities reading on a metropolitan scale shows the overflow of the agglomeration beyond the limits of the wilaya of Algiers, towards the south towards

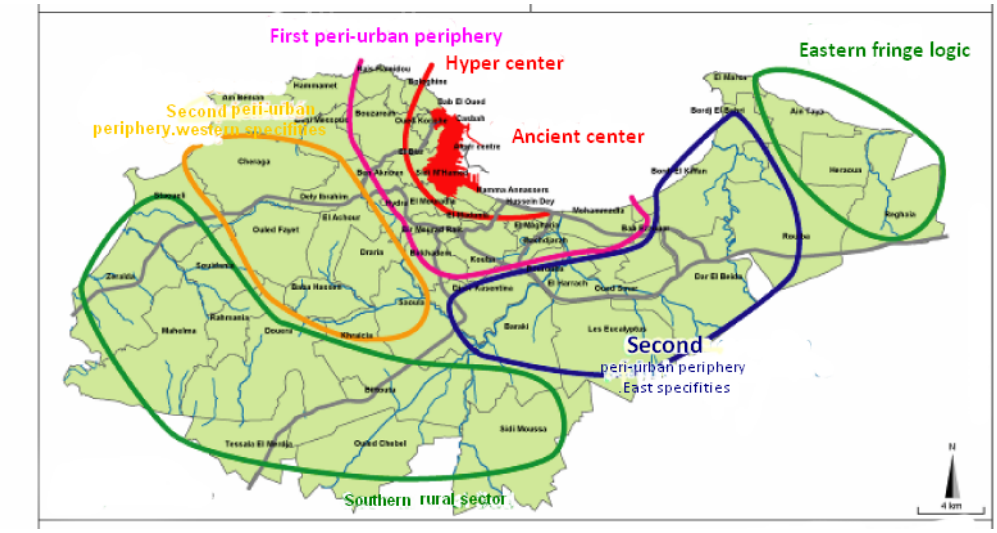


Fig. 4. Agglomeration of Algiers peripheries
Source: NAIT AMARA Farid (2012)

Blida, towards the west along the coast, towards Zeralda and towards the east around the international airport.

Urbanization issues

The urban analysis that we carried out in 2012 (updated for this article), allowed us to establish a spatialized socio-economic diagnosis with the following characteristics:

- It is based on the socio-demographic logics concomitant consideration, housing, activities and transportations;
- It allows deciphering the Algiers current dynamics agglomeration, and its development prospects;
- It highlights sub-territories, "territorial microzones", responding to specific operating logics and challenges.

Six sub-territories have been identified. They are structured according to a concentric logic, which starts from the historical heart of Algiers, extends into the hyper-centre and then spreads towards a, first and then a second, suburbs urbanization. This North-South structuring is coupled with a differentiated logic between the East and Westterritory, between more or less dense and spontaneous development forms inserted to the rest of the agglomeration. At each extremity East and West, fringes extend on a less sustained rhythm, the dynamics of development observed in their bordering territories.

As a final point in this chapter, we have tried to list the most important issues in the face of major risks on one hand, and the factors of vulnerability on the other, which are illustrated in Table No. 03 below.

From access Vulnerability to Algiers agglomeration

In order to assessthe vulnerability of accessibility, we chose to combinethe use of graphic simulation tool associated with a Geographic Information System to represent thenetwork road disruption, and the territorial access loss following a disaster. An impact scenario has been simulated, which is that of the 2003 seismic scenario (Boumerdes earthquake) and its impacts on the main road network of Algiers. In addition, we have tried to provide response elements in terms of socio-economic consequences, by graphically coupling the results of itineraries with the population the distribution and medical centers (major hospitals in Algiers).

In recent years, developments in thecomputer science field, particularly Geographic Information Systems (GIS), have facilitated the transport networks modelling and their integration into transport models. Since the use of GIS is dictated by the need to locate objects spatially with their geographical coordinates (X, Y), which makes the difference between the notion of the network in geography and other disciplines.

In order to abridge our approach including the detail has been developed in our PhD thesis,in the following we summarize the main steps to meet our objectives of accessibility comparison in normal times and in an earthquake situation:

- Recovery and updating of the main road network layer of the Algerian agglomeration (motorways, bypasses, expressways, national roads and Wilaya roads) in order to constitute the road graph and make topological correc-

Table 3. Vulnerability factors

Main Issues:	Vulnerability factors:
▪ Population : 5,300 000 inhabitants (2018) ▪ Housing: 638,804 dwellings (2008) ▪ Hyper centre: urban challenge, to be rehabilitated centre ▪ Patrimonial and historical issue (Casbah) ▪ Environmental issue: space to be protected in urban projects ▪ Command and governance post ▪ Economic fabric (industrial zones, business parks, ▪ Commercial and service activities cluster ▪ Airport: national and international connections ▪ Port: national and international maritime links ▪ Railways: interurban and regional links ▪ Road network: urban, interurban and regional links.	▪ Population growth ▪ Relatively high building vulnerability in the old center ▪ Very high building density ▪ Proliferation of precarious housing ▪ Heterogeneous population with unequal knowledge of risk and means of protection economic enterprises, etc.) ▪ Etc...

Source : Realized by authors

tions, prioritisation of roads with recourse to various sources (field surveys, topographical maps of Algiers, satellite images in order to assess accessibility in both situations (normal and earthquake).

- Drawing up a map of the vulnerability of the road network to an earthquake in collaboration with the technical services of the Directorate of Public Works of the Wilaya of Algiers.
- Calculation of accessibility between all the agglomerations of Algiers (57 agglomerations). It is accepted that the performance of the network depends on the quality of the infrastructure (number of lanes, network capacity, width of the road, road condition, etc.) At this level, performance is evaluated in terms of the speed that a road can have thanks to its technical characteristics. We can also combine other variables related to the road environment (relief, slope, sinuosity, urban environment, etc.), which act on the levels of speed practised. Speed can also be associated with the classification of the road (National Road, Wilaya Road, Highway, etc.) (Appert and Chapelon, 2003)
- Calculations of accessibility in a seismic risk situation with reducing speeds according to the vulnerability of each main road and its sections. And to clarify our approach, we carried out the same operation for the access times to the major hospitals in Algiers in normal times and in seismic situations.

Configuration of the Algerian main road network

On the basis of urban and functional analyses of the Algerian agglomeration and its mobility, the axes which play a major role in the mobility and movement of people have been identified and mapped according to a typology based on a hierarchy of infrastructures (highway, national road, wilaya road, etc.), and considers both quantitative and qualitative criteria and indicators (daily traffic, frequentation, usefulness and importance in the network ...). In addition to these indicators, the configuration of the infrastructure and its scale of service (local, urban, regional ...) must also be taken into consideration.

The main road network chosen is selected to represent the main backbone of the road infrastructure that will ensure better accessibility to the various capitals of the 57 communes in the Algerian agglomeration, and connect them to external areas: neighbouring regions.

An urban ring road function provided by the southern ring road and the eastern highway

Conceived as structuring infrastructures on a regional or even national scale, the southern ring road and the eastern highrway suffer from being used mainly for local services:

- Traffic is losing fluidity due to the cumulative use of transit and local service flows.
- The southern ring road is the backbone of the second ring road urbanisation, but its motorway-type development is not always adapted to its actual uses: urban bus stops on the emergency lanes and pedestrian traffic along the lanes.

A structure of secondary road chain, a factor of traffic congestion

- The secondary network, consisting of penetrating and trunk roads, converges radially towards the urban core, contributing to traffic congestion

Table 4. Speed assignment according to network characteristics (Chapelon, 2006)

Roads	Technical characteristics of infrastructures	Average traffic speed in off-peak hours (km/h)
R1	Highway	110
R2	Inter urban expressway: dual carriageway type motorway and main or regional connecting road with separate carriageway	90
R3	Urban expressway: highway or double carriageway of motorway type with reduced shoulder (<60 cm)	65
R4	Main or regional link road with 3 or 4 lanes or 2 widelanes, width:] 7m-9m]	70
R5	Main or regional link road with 2 “standard” lanes, width: J5m-7m]	60
R6	Main or regional link road and local service road with 1 or 2 narrowlanes, width: s 5m	50
R7	Urbanartery: penetrating or bypass structuring the urban road network	50
R8	Urban boulevard: main urban service road	35
R9	Street: local urban service road	25

in this area.

- While the second ring road is well served thanks to the motorway, the NR5 and 24 has a network of radial roads, the western part is little meshed outside the southern ring road. The Wilaya roads, remnants of its rural vocation, are in the majority, which will pose traffic problems if the population continues to increase in this area.
- The road network was originally designed for a town of 600,000 inhabitants and its expansion is strongly constrained by a steep site.

Road networks vulnerability of the Algerian agglomeration to a 2003-type earthquake

The classification of the main road network according to its vulnerability to a seismic hazard was carried out in collaboration with the Algiers Directorate of Public Works (DTP) during 2018, and on the basis ofmapping the vulnerability of the Algerian agglomeration to seismic risk relayed by the National Centre for Earthquake Engineering (NCEE).

The results of this classification are given in table no. 05 and shown in Fig. 7.

The first examination of the results of the Algerian road network vulnerability to seismic risk shows that :

- 42.98% of the road network (257.4 km) shows a very high level of vulnerability;
- 21.31% of the network is characterised by a high level of vulnerability;
- 29.74% of the main network shows a moderate level of vulnerability;
- Only 5.98% of the Algerian network in the event of an earthquake is characterised by a low level of vulnerability.

Table 5. Network road classification according to seismic risk vulnerability

Vulnerability level	Linear (Km)	%
Very high Vulnerability	257.4	42.98
High Vulnerability	127.6	21.31
Medium Vulnerability	178.1	29.74
Low Vulnerability	35,79	5.98
Total	589,90	100

Source: Realized by authors (June, 2019)

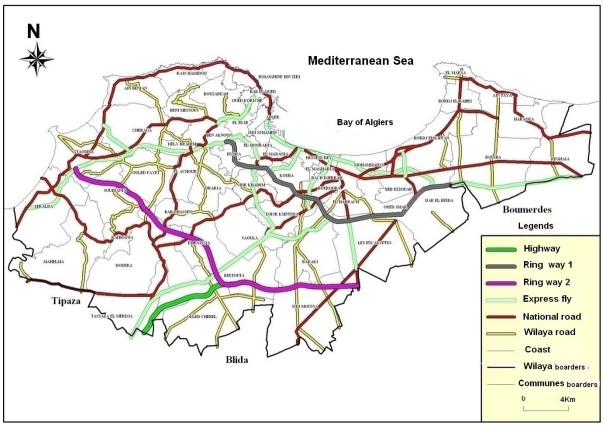
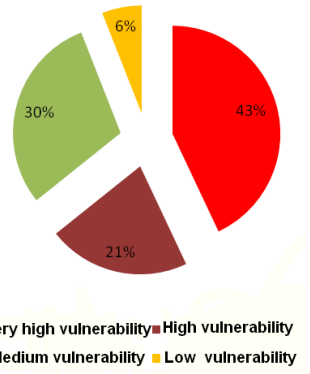


Fig. 5. The main road networks configuration of Algiers metropolis



Scheme 1. Road network vulnerability

In addition to the material factors combination which determine the vulnerability of the Algerian network, almost 65% of which is considered to be at high to very high risk, the accessibility function which ensures accessibility is called into question in various forms, either by the complete closure of the roads, or by the reduction in the theoretical accessibility speed which has been attributed to the roads according to their categories (ring road, national roads, wilaya roads).

In this article, and for the calculations of the accessibility in times of earthquakes, we considered the reduction of speeds on the axes according to their degree of vulnerability and on the observations made in the field by our surveys with the Directorate of Public Works in Algiers (speed reductions vary between 10 and 80%).

Comparison of accessibility to the agglomerations of the city of Algiers in normal

Situation and seismic risk situation

While the favourable conditions of accessibility by major traffic roads have contributed to favouring linear urban planning along these axes in the eastern part of the agglomeration, it is rather the availability of land that has been at the origin of the rapid

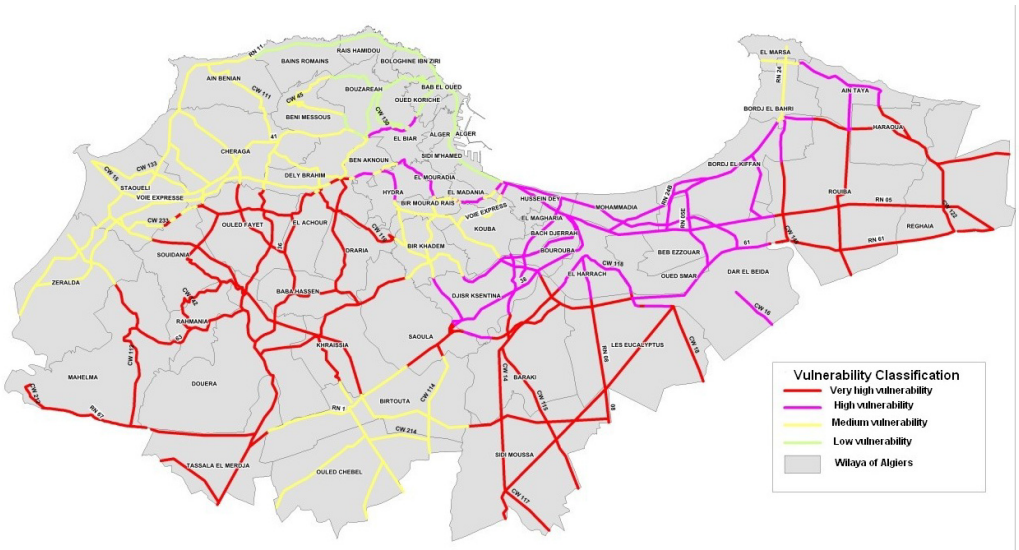


Fig. 7. Vulnerability map of the Algerian main road network
Source : Realized by authors

growth of the urbanization blocks of Chéraga, Draria and Baba Hassen in the south-west. The ring road construction around the dense central urban fabric of Ben Aknoun - Dar El Beida, carried out in the early 1980s, has also contributed to promote accessibility and hence the urbanization of the southern slope of this expressway. From aperipheral road ring, it has become in fifteen years a real median artery, dividing the urbanized space in two relatively equivalent parts in terms of demographic weight. Large informal housing spaces, built outside of construction standards, constitute one of the major challenges of prevention in the face of natural risks. Beyond the quality of the constructions which must be brought up to standard, it is also the development of these districts that must be taken into consideration: very small public spaces, under-equipment (health, education, security), the lack of clearance spaces for refugees and the cramped nature of the road network making accessibility difficult are all aggravating factors.

The table as well as the Figures (10 and 11) highlight on one hand the general times of accessibility between the 57 agglomerations in minutes that Algiers counts as well as the average access time for each agglomeration and for the totals, and averages have been calculated in two situations: Normal situation and situation of a typical earthquake in 2003.

This method provides two types of results: - a vulnerability index allowing to rank the accessibility vulnerability of Algiers agglomerations in normal and seismic risk situations, - a distribution of damage probabilities over the agglomerations in the event of an earthquake, which depends on the seismic intensity considered (EMS 98 scale).

Therefore, this method has the advantage of providing both criteria for decision -making on the priorities for in-depth studies or reinforcement of the existing road network (through the hierarchy obtained), and an idea of the behaviour of each lane in the event of an earthquake. In addition, it has the advantage of associating uncertainty with the vulnerability index obtained.

Scheme 2 presents a comparison of access times from the centre of Algiers to the rest of the commune 56 chief towns (CCTs), with an average difference of 65.8 minutes between normal time and earthquake situation (Min transportation from the center of Algiers to all CCTs).

Accessibility to the main hospitals in a seismic situation

The wilaya of Algiers has a substantial offer of care, whether in the public or private sector; the hospital capacity seems sufficient (if it were intended only for the population of Algiers). Analysis of the distribution of light structures shows a deficit in the communes of the wilaya southwest. The medical human resource is plethoric (in connection with the desire of medical specialists to be kept in Algiers within the framework of the civil service and the feminization of the various bodies of health).

Table 6. Comparison of access time between Algiers agglomerations in normal times and earthquake situation

Communes	Access time normal speed (Min)		Access time in earthquake situation		Differences between normal times and earthquake situation (Min)			
	General Total	Average	General Total	Average	Difference General total	%	Difference Average	%
Ain Benian	1069,7	18.8	3846.9	67.5	2777.20	72.19	48.70	27.81
Ain Taya	1539,4	27.0	6441.9	113.0	4902.50	76.10	86.00	23.90
Center of Algiers	769,4	13.5	3068.8	53.8	2299.40	74.93	40.30	25.07
Bab El Oued	829,0	14.5	3055.4	53.6	2226.40	72.87	39.10	27.13
Bab Eezzouar	891,4	15.6	4068.5	71.4	3177.10	78.09	55.80	21.91
Baba Hassen	915,4	16.1	6257.5	109.8	5342.10	85.37	93.70	14.63
Bachdjarah	806,4	14.1	3518.2	61.7	2711.80	77.08	47.60	22.92
Baraki	828,4	14.5	4890.6	85.8	4062.20	83.06	71.30	16.94
Ben Aknoun	711,0	12.5	3562.1	62.5	2851.10	80.04	50.00	19.96
Beni Messous	897,1	15.7	3743.9	65.7	2846.80	76.04	50.00	23.96
Bir Mouradrais	649,5	11.4	3093.1	54.3	2443.60	79.00	42.90	21.00
Birkhadem	734,4	12.9	3333.3	58.5	2598.90	77.97	45.60	22.03
Birtouta	1000,6	17.6	5678.3	99.6	4677.70	82.38	82.00	17.62
Bologhine	868,5	15.2	3146.8	55.2	2278.30	72.40	40.00	27.60
Bordj el bahri	1303,0	22.9	5582.5	97.9	4279.50	76.66	75.00	23.34
Bordj el kiffan	1009,9	17.7	4312.9	75.7	3303.00	76.58	58.00	23.42
Bourouba	763,1	13.4	3451.6	60.6	2688.50	77.89	47.20	22.11
Bouzareah	768,4	13.5	3421.6	60.0	2653.20	77.54	46.50	22.46
Casbah	812,8	14.3	2997.9	52.6	2185.10	72.89	38.30	27.11
Cheraga	867,1	15.2	3663.7	64.3	2796.60	76.33	49.10	23.67
Dar el Beida	975,8	17.1	4699.2	82.4	3723.40	79.24	65.30	20.76
Dely Brahim	815,1	14.3	3463.2	60.8	2648.10	76.46	46.50	23.54
Djasr Kassentina	740,4	13.0	3463.4	60.8	2723.00	78.62	47.80	21.38
Douera	983,9	17.3	7694.5	135.0	6710.60	87.21	117.70	12.79
Draria	873,1	15.3	5850.7	102.6	4977.60	85.08	87.30	14.92
El Achour	773,3	13.6	4241.8	74.4	3468.50	81.77	60.80	18.23
El Biar	710,0	12.5	3387.2	59.4	2677.20	79.04	46.90	20.96
El Harrach	821,9	14.4	3599.8	63.2	2777.90	77.17	48.80	22.83
El Madania	662,7	11.6	3375.7	59.2	2713.00	80.37	47.60	19.63
El Magharia	724,7	12.7	3429.2	60.2	2704.50	78.87	47.50	21.13
El Marsa	1407,5	24.7	5830.3	102.3	4422.80	75.86	77.60	24.14
El Mouradia	673,2	11.8	3431.8	60.2	2758.60	80.38	48.40	19.62
Eucalyptus	945,6	16.6	6967.8	122.2	6022.20	86.43	105.60	13.57
Hammamet	1040,1	18.2	3552.3	62.3	2512.20	70.72	44.10	29.28
Haraoua	1553,5	27.3	7934.8	139.2	6381.30	80.42	111.90	19.58
Hussein dey	710,2	12.5	3134.3	55.0	2424.10	77.34	42.50	22.66
Hydra	723,3	12.7	3751.6	65.8	3028.30	80.72	53.10	19.28
Khraicia	930,4	16.3	6792.4	119.2	5862.00	86.30	102.90	13.70
Kouba	720,7	12.6	3108.2	54.5	2387.50	76.81	41.90	23.19
Mehelma	1235,5	21.7	6446.6	113.1	5211.1	80.83	91.40	19.17
Mohamed Belouizdad	706,3	12.4	3022.8	53.0	2316.5	76.63	40.60	23.37
Mohammadia	825,6	14.5	3552.8	62.3	2727.2	76.76	47.80	23.24
Oued Koriche	852,9	15.0	3121.3	54.8	2268.4	72.67	39.80	27.33
Oued Smar	889,6	15.6	3895.1	68.3	3005.5	77.16	52.70	22.84
Ouled Chebel	1299,1	22.8	5914,6	103.8	4615,5	78.04	81.00	21.96
Ouled Fayet	886,0	15.5	4464.8	78.3	3578.8	80.16	62.80	19.84
Rahmania	1212,6	21.3	8218.2	144.2	7005.6	85.24	122.90	14.76
Rais Hamidou	969,8	17.0	3353.3	58.8	2383.5	71.08	41.80	28.92
Reghaia	1363,9	23.9	10778.3	189.1	9414.4	87.35	165.20	12.65

Source: Realized by authors

Table 6. *Continued ...*

Communes	Access time normal speed (Min)		Access time in earthquake situation		Differences between normal times and earthquake situation (Min)			
	General Total	Average	General Total	Average	Difference General total	%	Difference Average	%
Rouiba	1196,2	21.0	7183.2	126.0	5987.0	83.35	105.0	16.65
Saoula	798,2	14.0	3917.5	68.7	3119.3	79.63	54.70	20.37
SidiM'hamed	719,2	12.6	3004.6	52.7	2285.4	76.06	40.10	23.94
Sidi Moussa	1155,2	20.3	9220.6	161.8	8065.4	87.47	141.50	12.53
Souidania	1049,9	18.4	6320.1	110.9	5270.2	83.39	92.50	16.61
Staoueli	1030,1	18.1	4291.8	75.3	3261.7	76.00	57.20	24.00
Tessala El Merdja	1054,6	18.5	6622.5	116.2	5567.9	84.08	97.70	15.92
Zeralda	1101,7	19.3	4900.6	86.0	3798.9	77.52	66.70	22.48
General total	53166,2	16.4	267072.3	82.2	213906.1	80.09	65.80	27.81

Source: Realized by authors

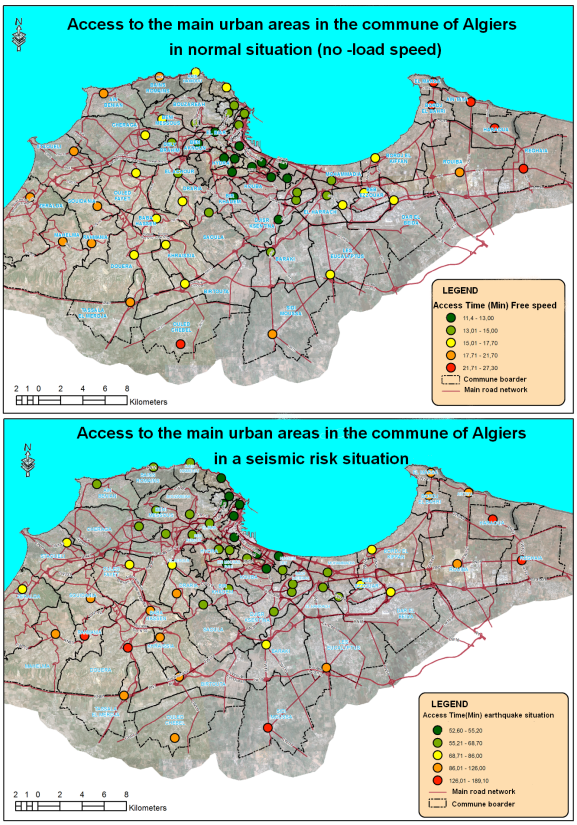


Fig. 8. Algiers accessibility in normal times and in earthquake situation
Source: realized by authors (November 2020)

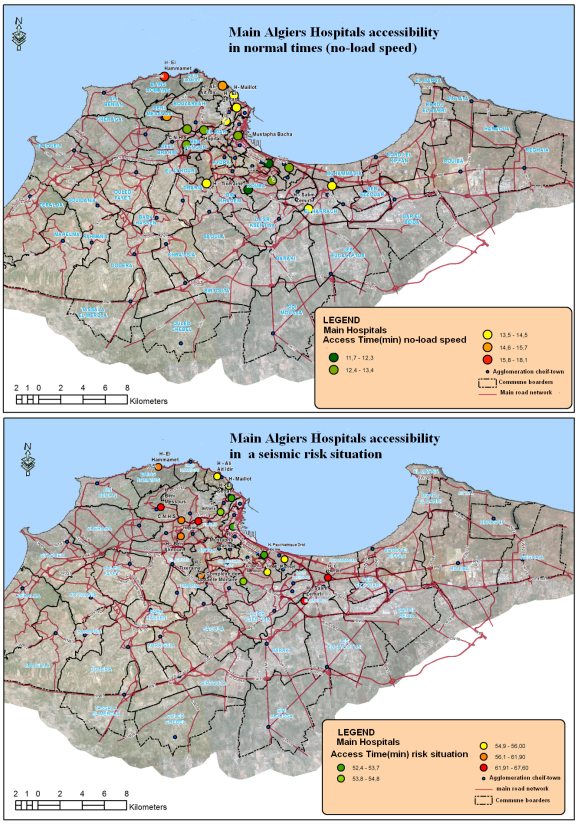
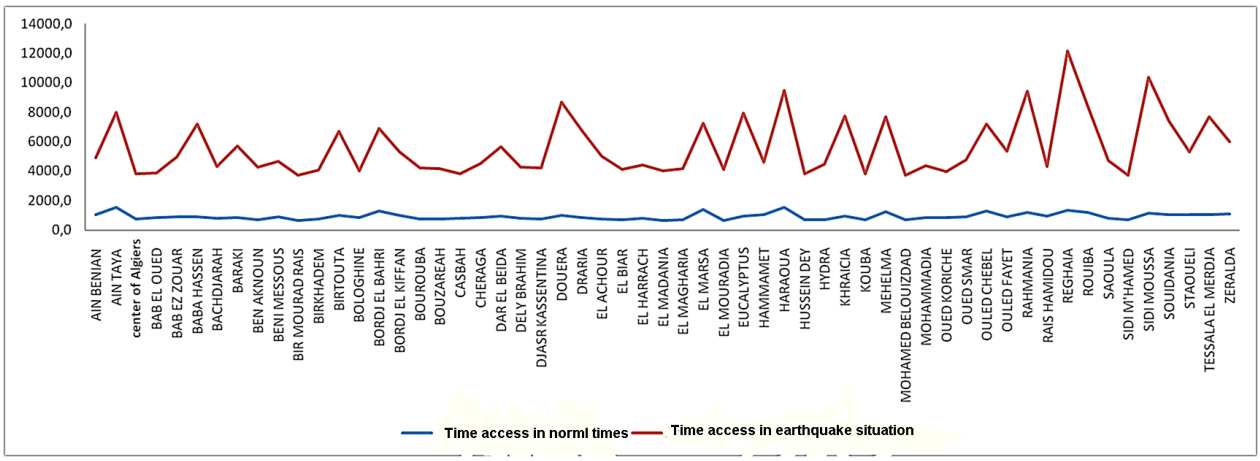
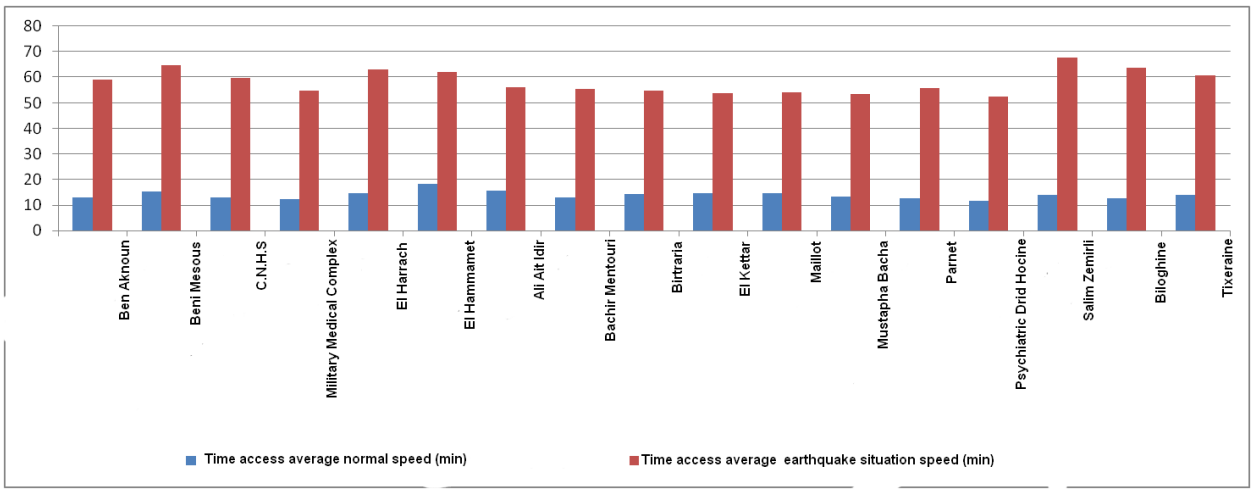


Fig. 9. Accessibility to the main hospitals in a seismic situation
Source: realized by authors (November, 2020)

When a natural disaster strikes, critical or civil protection infrastructure is called upon to play a crucial role in emergency response. Hospitals, in particular, must remain operational during and after a major earthquake. This ability to ensure the quality of operations while guaranteeing the safety of occupants during and after an earthquake refers to the notion of post-seismic functionality. Observation of damage from recent earthquakes shows that the functionality of a hospital is linked to the good



Scheme 2. Comparison of access times between agglomeration in normal and earthquake situations (By the authors).



Scheme 3. Access time Average normal speed and speed in an earthquake situation to the main hospitals in Algiers. *Source* : Realized by authors

performance of the structure and the functional and operational components (FOC) in their functional environment and not in isolation. FOCs include all the architectural and technical components, specialized equipment, content as well as essential infrastructure services. The results in a group y of systems and sub-systems linked by their interfaces and usually described as complex, making it difficult to determine the overall seismic performance. In order to draw up the framework for evaluating the accessibility of the main hospitals in Algiers in normal and post-seismic times as shown in Table 7, Figure 11 below.

The average accessibility to the major hospitals in Algiers can be expressed in a relatively numerical way in an earthquake situation with a difference of 47.69 mn, which makes the rescue process difficult.

In the city of Algiers, as shown in Table 07, average distance-time of access to hospitals is around 58 min. However, the hospitals of SalimZmerli and beni Messous are characterised by an access time higher than this average (between 65 and 68 min), as well as hospitals located in the northern part of the city, such as the hospital of Benaknoun, (time higher than 59 min), due to an even higher concentration of the latter than on the Algiers slope, essentially in the main hospitals (Bachdjerah and Elharrache).

What is remarkable in Algiers are the significant differences between the level of accessibility of public transport and passenger transport. The absence of a network vision of the transport system, which results in theline culture predominance, poor articulation of the different modes and operators, and precarious managementare the main reasons for the

Table 7. Access timeaverage normal speed and speed in earthquake situation of main hospitals in Algiers.

Hospital	Average access time normal speed (Min)	Average access time earthquake situation speed (Min)	Differences between normal time and earthquake situation (Min)	
			Difference Average (Min)	%
Ben Aknoun	13,03	59,25	46,22	454,84
BeniMessous	15,31	64,67	49,35	422,25
C.N.H.S	13,08	59,81	46,74	457,39
Complexe de la Santé militaire	12,26	54,81	42,55	447,13
El Harrach	14,44	62,93	48,49	435,85
El Hammamet	18,10	61,93	43,83	342,16
Ali Ait Idir	15,69	55,97	40,28	356,69
BachirMentouri	12,88	55,32	42,44	429,60
Birtraria	14,24	54,80	40,55	384,75
El Kettar	14,53	53,68	39,15	369,45
Maillot	14,55	54,07	39,52	371,59
Mustapha Bacha	13,39	53.36	39.96	398,37
Parnet	12,63	55.85	43.22	442.34
Psychiatric DridHocine	11,72	52.40	40.68	447.07
SalimZemirli	13,87	67.65	53.77	487.66
Bologhine	12,78	63.64	50.86	498.10
Tixeraine	13,90	60.69	46.79	436.59

Source :Realized by authors

difficulty of public transport accessibility in Algiers. The transport system real challenge in Algiers is to be able to articulate "center-periphery" and especially "periphery-periphery" pendular transportation.

Conclusion

This paper aimed to present a method highlighting certain dimensions of territorial vulnerability, taking as an approach the vulnerability of thematerial and logistical supports of daily mobility.

This research starts from an in-depth analysis of the mobility organization and functioning, in the city of Algiers. This knowledge allows discerning the key infrastructures of road and transport networks, the damage or loss of which would be detrimental to the district. The key-infrastructures vulnerability was assessed by considering six inputs which provide information on their propensity to be out of service. This loss of operationality in turn implies a decrease in the integrity of the network. The latter helps to understand the mobility problems that can arise in a territory, and certain sectors vulnerability of the accessibility. The reduction of sectors' accessibility attests to a form of vulnerability of the populations residing there, and for the urban functions located there. Finally, from there, it is possible to understand, on a greater scale, the urban territory vulnerability as a whole, through different scenarios.

Thus, the results obtained permit to offer a useful basis for reflection to the various urban actors, and to the local authority of the commune of Algiers. The updated geo-referenced database and the maps produced constitute tools and support for the decision for preventive planning and risk management.

For example, proposals for marked road alternatives have been defined to compensate for the closure of tunnels, highly vulnerable and essential infrastructures to link the north and south of the city. The structural reinforcement of the few key bridges identified among the most vulnerable to earthquake would prevent their collapse. When this solution is not technically or financially possible, the storage of reconstruction material nearby would facilitate their rehabilitation. Similarly, targeted investments in roads would improve the accessibility of the few sectors with strategic urban functions that are most exposed to isolation. In the same vein, relocating certain strategic urban facilities to areas with less risk of isolation, or thebranches spatial deconcentration would enable the district to face more effectively to a crisis. Finally, it could be planned to make the construction of several access roads compulsory for new housing estates.

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