STREET CONNECTIVITY AND MOBILITY: CASE OF SUBDIVISIONS, TLEMCEN CITY, ALGERIA

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Key-words: accessibility, street layout, legibility, public health, walk ability.

Abstract. During the 20th century, the specialization of road function adopted by designers, showed its limits. The main street network is geared towards mechanical traffic and speed, at the expense of walking and public transit. This approach has created enclaved areas and isolated neighbourhoods in the city where the inhabitants are dependent on car. This has created public-health problems related to the immobility of citizens and greenhouse gas due to the saturation of the network. Street connectivity is essential to facilitate and diversify travel modalities. However, we demonstrate that an acceptable connectivity index of the inner subdivision streets remains insufficient for its proper functioning. We show that a hierarchy of roads clearly expressed, legibility, easy accessibility to the subdivision and the continuity of the main streets of the city are a determining factor to facilitate and diversify travel modalities. This provides the mobility of pedestrians and reduces the use of cars. Based on the study of former fabrics and the results of current scientific research, we have deducted the conceptual rules favouring coherence and facilitating the mobility of users. In order to verify the impact and to give a concrete form to these fundamental rules, the city of Tlemcen is chosen as a case-study. This analysis allowed us to show that the performance of the layout of the inner road of the subdivision also depends on the efficiency of the main road network of the city. Both scales must be studied simultaneously.

1. INTRODUCTION

Universally, the subdivision process is one of the oldest modalities of urban space creation; from the Roman cities to the Bastide in the 13th century and the industrial cities of the 18th century to the garden cities theorized by Howard in 1898 (Paquot, 2011). This simple and regular modality allowed these cities to evolve and their urban fabrics to become more complex (Mangin *et al.*, 1999). This traditional street layout, characterized by the grid, was criticized by architects and town planners at the end of the 19th century. It was considered monotonous and not well-adapted to natural topographical features (Handy, 2003; Harris, 2007). The choice was rather focussed at that time on using dead-end streets, curved and discontinuous streets, to discourage vehicle traffic in neighbourhoods. As a result, today in the residential areas of Europe (Héran, 2011), and the United States (Handy, 2003), residential streets are separated from commercial streets. Over time, this practice was popularized and created thereafter residential areas with low street connectivity and representing urban enclaves in the city (Héran, 2011; Yung *et al.*, 2016). By comparison, many old towns were originally purely residential, being transformed into urban centers thanks to their good connectivity permitted by their simple and regular street-network layout. For this reason, Harris (Harris, 2007) and Handy (Handy, 2005a) noted a renewed interest in this kind of design in the United States.

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In several countries, characterized by strong demographic expansion, including Algeria the subdivision was and remains a way to answer the urgent and the increasing need for housing; “it is one of the most appropriate frameworks for citizen participation in the construction effort” (Ministry of Urban Planning and Construction, 1990). The subdivisions have a significant share in this growth process, including the expansion of cities. However, this situation has generated, in a short time, the construction of a great number of subdivisions. These are the conditions that led to the "poor" quality (Ministry of Urban Planning and Construction, 1990) urban landscape of our cities which are already victims of uncontrolled and excessive development (Ministry of Infrastructure and Spatial Planning, 1998).

This work focuses on planned subdivisions as a modality of urban fabric production, specifically the road network role in this process. The infrastructure system should be multipurpose, interconnected and synergistic in the urban fabric (Brown, 2014). This topic arose, following the reports released on the increase of this type of operations in Algeria and the application of the interdepartmental instruction relating to the relaunching of the habitat (Interministerial Instruction Relating to the Revival of Housing No. 1., 31 May, 1994). In addition, this issue is attracting the interest of the scientific community. BETUR (BETUR, 2013) has a study carried out as part of the development of Tlemcen city traffic states plan that: “The flow of Personal Vehicles (PV) is the most common modality and reaches 72.55% (79209 PV) of the total daily traffic, and public transport represents only 13%”. The study states that 45.19% of the trips are not necessary (shopping, visits, ...). The question is: how this urbanization, qualified as “poor and anarchic” by the Ministry of Infrastructure and Spatial Planning, is leading the subdivisions practice in Tlemcen?, and how the road network layout of the subdivision is affecting street connectivity and citizen mobility?

To answer these questions two objectives have been set: The first is to study the role of the city’s main road network in connecting the subdivision to its environment. The second is to explore the impact of the subdivision internal road network organization on the connectivity of its streets and its functioning (mobility, accessibility, etc.).

2. METHODOLOGY

Two scales are processed, the first one concerns the main road network of the city. The objective is to study its role and how it links the subdivision with its environment. This simple and regular modality allowed these cities to evolve and their urban fabrics to become more complex (Héran, 2011). It is also connected to the various entities of the city, including subdivisions. These main road networks structure the districts and organize them. Based on a reading of the layout of various subdivisions throughout history, this work will show how the primary road layout of the city structured and linked the different subdivisions and entities. An evolutionary reading of the notion of subdivision was made. This operation has shown its ability to evolve. It is moving from a purely regulatory kind, which first sought to remedy the insanitary installations, the creation of neighbourhoods and urban centers in their own right. This resulted in the complexity of the urban fabric and the evolution of its road network conditioned by several factors (Garrison, 1990).

After that, it appears therefore necessary to study the second scale, that explores the organization impact of the subdivision internal road network and its connectivity to the subdivision functioning (mobility, accessibility, etc.). In reference to the subdivision morphology, the road network is the determining factor. Additionally, the street layout allowed it to evolve and to move from simply sharing and residential streets to the urban fabric complexity with the diversity of its activities and landscape (Mangin *et al.*, 1999). The residential streets have been transformed in boulevards and avenues, and have become the support for various networks which are still growing (sanitation,

drinking water, gas, phone, etc.). The ever-increasing mobility made streets the areas where networks overlap automobile traffic, pedestrians, cycle traffic and public transportation.

Current studies focus on the relationship between the shape of the road network and its ability to evolve and meet new needs (Mendiolaa *et al.*, 2014). The road network is the permanent element of the urban fabric. In time, everything tends to change and morph in the urban fabric except for the road layout, which is perpetuated and protracted (Brès, 1998). However, streets serve continuous mutation of spaces. Their structure is durable, but their overall configuration must be adapted to accommodate internal new uses, external mobility and the use of the land it serves (Mendiolaa *et al.*, 2014). The physical environment is only one component of lived space (Christens, 2009), but it remains, however, the support of other elements, social, economic and cultural.

The use of the conceptual principles of old subdivision layout allows the emergence of cities with their urban centers, supports of various activities. The regularity, simplicity and the rationality of the street layout network are the principal characteristics of the urban fabric of these subdivisions. They promote street connectivity. This criterion encourages the functional diversification and the complexity, so wanted in old urban fabrics. Street connectivity allows and facilitates access to business areas (Cerdá *et al.*, 2010). This mode of operation offered by the road network, based on the connectivity of roads, is the opposed to monotonous and stereotyped areas. The connectivity assumes the creation of multiple, alternate routes for automobiles and several road options for the pedestrians and the cyclists (American Planning Association, 2006). Also, it makes fear the designers for the risks and the lack of security in residential areas. Creating neighbourhoods with low street connectivity and relocating no residential uses to arterial street appears as a solution to reduce the risk, in reality it transfers the problems of security to other areas which will be more saturated (Dumbaugh *et al.*, 2009). Additional measures must be taken for safest roads between origins and destinations. So streets can be designed not to be only safe, but to be also livable and better for us all (Dumbaugh *et al.*, 2005). Several studies investigating the process for good connectivity have a good perception of street space in favour of the citizens' health and a better mobility (Jiang *et al.*, 2011; Knight *et al.*, 2015; Rahimi *et al.*, 2014; Trovalla *et al.*, 2015; Yang *et al.*, 2011). The psychological and physical dimensions of shared space are very much interconnected (Hickey, 2014).

Mangin and Panerai (Mangin *et al.*, 1999) offer an analysis grid that allows identifying the conceptual subdivision rules. They show that this mode of ground cutting operation has existed for a very long time. Cities were created on the basis of regular agricultural tracings, case of Cairo in Egypt, Gmare in Algeria (Fig. 1) (Bousserak *et al.*, 2018) and the industrial cities in Europe, or the new cities of the United States. The spatial organization laws governing the subdivision arise from these old practices. The study of the road network of these cities and medinas was elaborated. As a result, the street hierarchy and the main road continuity lead to the coherence and functionality of the whole. Many studies show that there is a relationship between urban morphology and mobility (Sung *et al.*, 2015). Mobility results from the configuration of the urban network, at the same time the conditions of the mobility model the configuration of the urban network (Wiel, 2002). Consequently, the shape of a street network facilitates or hinders the mobility of individuals and their mode of travel (Hillier, 1996; Wiel, 2002). Roads interruptions can be an obstacle, it is fragmenting space and obstructing the continuity and consistency between the various entities (Héran, 2011). This hinders the diversity and social equity necessary for the survival of urban centers. It must create functional, coherent neighbourhoods and allow a healthy life for citizens (Lobo, 2010; Mele, 2014).

The specific case of Tlemcen is studied on the basis of this theoretical knowledge. The street layout of the city's old center (Ghoumari, 2009) responds to the principle of spatial organization which we have already observed in the readings of the cities we have studied. But what about its new planned subdivisions?

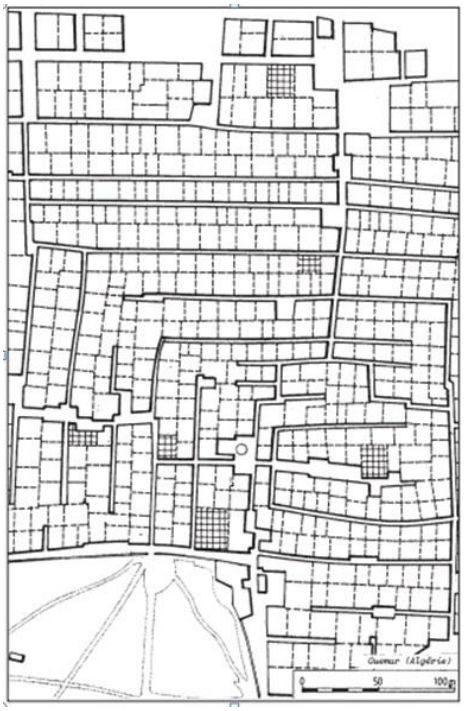

Fig. 1 – Regular street layout executed on the basis of the agricultural tracing. Former core, Gmare, Algeria, (Mangin *et al.*, 1999).

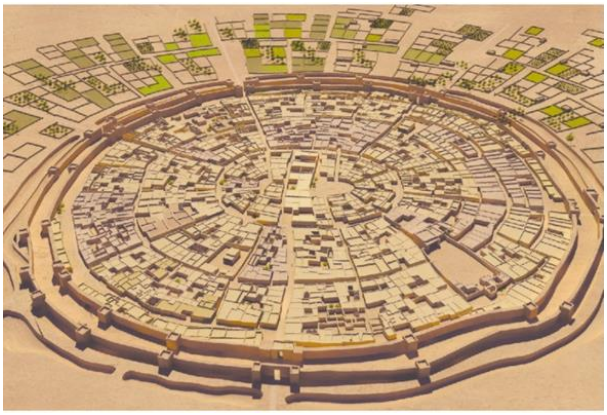

Fig. 2 – Regular street layout of Al-Rawda City, Syria (Kanjou *et al.*, 2016).

2.1. The regulation: the subdivision in Algerian legislation

The subdivision is a tool of town planning having allowed the creation of building land. The way in which the subdivisions were achieved in our country has led to a visible "mediocrity" denounced by the Ministry of Housing and criticized by all (Ministry of Infrastructure and Spatial Planning, 1998). Subdivision is allowed after the approval of the subdivision permit. This must follow the plan, the indications and the recommendations of the Development Plan and Town Planning and those of the Land-use Plan where they exist, otherwise the general rules of town planning (urban planning code, 2014). All these tools have remained powerless against the increase of housing developments generating a multitude of anomalies (urban planning code, 2014). Legislation and regulations tend to rational and balanced land use.

2.2. The subdivision in the theory: conceptual rules of subdivision

Generally, the subdivision operation has contributed to the creation of the city. It, therefore, allows the transition from the simple division of the ground to the urban fabric complexity (Mangin *et al.*, 1999). The regularity of urban plans, the rationality and the simple layout in favour of economy, were subdivision characteristics. Road connectivity favours also the complexity of the urban fabric through time. This is considered as an important criterion of urban sustainability (Gurran, 2011; Stangl *et al.*, 2011). The initially simple tissues of subdivisions, designed to accommodate individual dwellings, became developed and more complex, and had given birth to cities and urban centers (Hadas, 2016).

2.2.1. The role of the main street network and it interaction with the internal street network of the subdivision

Studying several street layout networks of subdivisions around the world has enabled us to understand their organisation mode. They are arranged in connection with the arterial street network of the city, the layout of street which defines their forms. Regularity and simplicity are the street layout characteristics of the old world cities, this promotes pathway connectivity (Omer, 2015). For example, Al-Rawda City cited by Kanjou and Tsuneki (Kanjou *et al.*, 2016). Its geometric layout shows the continuous and straight structuring pathways and connecting the center with the various city gates, as shown in Figure 2.

a. Street hierarchy[1]

A clearly hierarchical network allows an explicit differentiation of the types of itineraries recognizable by the fact that they are both clearly ordered and connected coherently to one another. These components have a clear classification order related to the global spatial arrangement (Marshall *et al.*, 2010). The interaction of the main streets of the city and the internal streets of the subdivision is formalized by the subdivision's distribution roads that originate from the main roads on a hierarchical basis. Hence, the subdivision will have several accesses from the principal street network. The enhanced accessibility ensures better access and at the same time reduces the need for travel (Handy, 2002). Its structuring roads are continuous. They organize the internal distribution and connect different subdivisions together (when it is a question of grouping several subdivisions), or a subdivision with its environment. In addition to street hierarchy, the "legibility"[2] the "imageability"[3] allow to locate you throughout the roads and to discover and understand the morphological and the topological structure of the road network.

b. Streets continuity

The arterial roads of each subdivision of the city structure connect the different operations. Consistency between them liyes in the extension of their main road, from which the distribution streets of each subdivision will be hierarchized. This connecting road must be well designed, so it is not an obstacle and a separation split break between the entities (Handy, 2002). The continuity and regularity characteristics of roads promote the economy by reducing the distance. The road is the support of various networks (sanitation, water supply, electricity, gas, etc.). Reducing its linearity affects the overall cost of implementation and maintenance projects. Mangin and Panerai (Mangin *et al.*, 1999) called this practice "rational" cutting ground.

c. Accessibility

This mode of operation is not only summarized in the economy, it additionally allows a permeability of the urban fabric which facilitate citizen travel. Better accessibility is achieved by fewer network turns (Henson *et al.*, 2003). The configuration of the layout road network, is the main generator of patterns of movement (Hillier *et al.*, 1993). Improving accessibility contributes to the improvement of transportation systems (Handy, 2005b; Straatemeier *et al.*, 2008). Accessibility can also be used as a sustainability indicator in land-use planning (Dumbaugh *et al.*, 2009). When structuring roads are continuous, they organize the internal distribution and connect different subdivisions together. Accessibility and continuity of routes promote access to different areas and increases choice. This street layout so establishes offer a connectivity to the roads service which determines access to

[1] **Hierarchy targeted in this work**: A clearly hierarchical network allows an explicit differentiation of the types of itineraries recognizable that are both clearly ordered and connect coherently to one another. These components have a clear classification order related to the global spatial arrangement.

[2] **Legibility**: Readable network easy to understand (Marshall, 2005). Illustrates its ability to create a perception of the territories, to make it possible to identify oneself throughout the travel whose street network constitutes the support.

[3] **Imageability**: Term used by Kevin Lynch, (Lynch, 1960).

opportunities for physical activity and healthy eating (Handy *et al.*, 2007; Matan *et al.*, 2015). This factor tended to have more walking, biking, and transit use (Marshall *et al.*, 2010).

d. Connectivity and mobility

Mobility is closely-related to connectivity. They are so closely linked that they become inseparable (Wiel, 2002). Mobility resulting from the urban layout, however, these conditions of mobility model the urban layout (Wiel, 2002). The "conventional hierarchy"[4] of roads tends to produce a large mesh that surrounds neighbourhoods and favour speed. So, this road hierarchy favours the mechanical movement (Héran, 2011). For pedestrian movement and to facilitate access to services and particularly emergency service, the network should be finely meshed with an efficient secondary road and continued (Héran, 2011; Litman, 2016). This street connectivity preserves the user's health by promoting walking. Several researches are addressing this issue (Ewing *et al.*, 2009; Lowe *et al.*, 2015; Macintyre *et al.*, 2002; Tribby *et al.*, 2016; Vermotea *et al.*, 2014). Connected street networks provide a framework that produces a social and functional coherence that can provide public services in a highly efficient way and that can adapt to change (Dill, 2004; Netto *et al.*, 2015). Additionally, the flow of traffic can be diversified in many areas, enabling travel choices other than driving. This improves overall mobility and helps to reduce congestion on overused arterial (Handy, 2003). We must create models to achieve reductions in transport energy. The interconnection between service roads offers additionally the possibility of implementation of a more efficient transport service (Handy, 2003; Khan *et al.*, 2014). One can show how the roads interruptions can fragment space and obstruct the continuity and consistency between the various entities (Rifaat *et al.*, 2012). This creates a difficulty to move for pedestrians and access to services. So, the subdivision street layout should allow connectivity of the roads and various spaces of entity. The street hierarchy is then necessary to ensure good permeability of the urban fabric (Jiang, 2009). This facilitates the various travel modalities and encourages walking, which positively affects the citizen's health (Healthy Spaces & Places, 2009). Recent studies have shown the link between the health of the user's and subdivision street connectivity, where for those not connected, residents are depending of the car. However, those well connected favoured residents walking and cycling (Frumkin *et al.*, 2004). A sedentary lifestyle increases the risk of cardiovascular disease, stroke, diabetes, and obesity (Frumkin *et al.*, 2004).

In the United States, several cities require opening the new subdivisions for traffic to facilitate various motions. A connectivity ordinance sets a minimum number of network connectivity. These cities recommend an index of value 1.4 minimum and the value 1.6 is preferred (Handy, 2003). The connectivity index is the ratio between the number of segments and the number of nodes of a network (Handy, 2003).

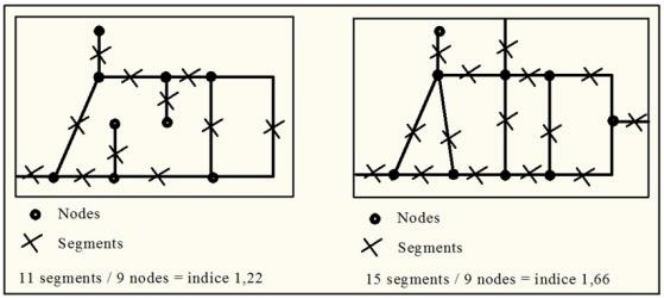

Fig. 3 – Calculation of the connectivity index.
Figure produced on the basis of Susan Handy work (Handy, 2003).

[4] **Conventional hierarchy**: deemed non-functional that promotes mechanical traffic and speed. The main routes in this case represent an obstacle and they enclave the areas they surround (Marshall, 2005).

This figure provides an example of how to calculate the connectivity index. Another constraint is added to this index, it is the limited length of dead ends and blocks most often between 100 m and 200 m (Handy, 2003).

3. RESULTS

The legislative texts and the rules which result from it are in accordance with the design principles of the subdivision: however, the interministerial instructions reveal a non-compliance with what is done in the cities of the national territory in relation to the rules. Tlemcen a town in the Algerian North west, whose population reached about 949.135,0 inhabitants (National Statistics Office, 2016), has not escaped the excessive growth that hit most of its suburban areas. Individual housing occupies most urbanized areas. It then offers an interesting study-case (Fig. 4).

Local application: the subdivisions at Tlemcen

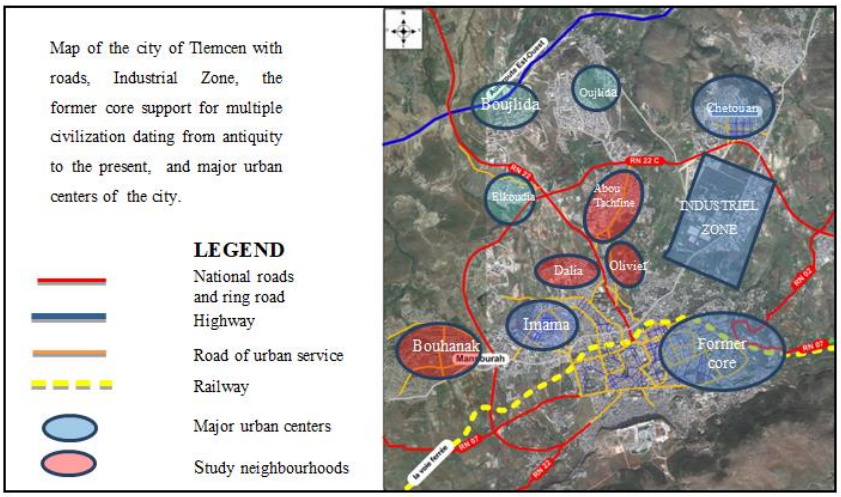

Fig. 4. Functional areas and transport infrastructure of Tlemcen. Map produced on the basis of the plan of urban infrastructure drawn from the traffic plan of Tlemcen BETUR done by the Design Office in March 2013 (BETUR, 2013).

This proliferation concerns older kernels and also new sites on a peripheral belt (Hamma *et al.*, 2016). They form small clusters along the ring road east to west, letting appear "no man's land". This creates a discontinuity or rupture between the different entities in the city. Thus, the difficulty to reach any part of the city is felt. How is this translated into the road network of subdivisions? The observation of the layout of the roads of the different subdivisions of the city and its comparison with the conceptual principles presented above made it possible to draw some conclusions.

3.1. The main roads of the city

Urbanization in Tlemcen was made in the form of subdivision, or in the form of new urban zones of housing environment (ZHUN). Depending on the location, subdivisions are placed in the middle of a city area, either in the clustered form making up an urban entity, or in the isolated form. In both cases the road network must play the role of the authorizing officer. It must structure and connect different parts of it. The notice by observing the urban groups of Bouhanak and of Abou Tachfine for example, that the structuring roads of the city do not cross the group, but bypass it. This involves a problem of subdivision accessibility which is not done directly from the continuous road to urban

centers. The resulting of various bypasses and break of access roads to subdivisions and the absence in most cases of a hierarchy of roads clearly expressed, create difficulties of localization and imply longer distances to do in these groupings. It implies difficulties to identify the shortest street between different points of the subdivision. This leads to saturation of some main streets and crossroads. It should be noted that 45.19% of the trips are not necessary (shopping, visits, etc.). With better access to basic services this percentage can be reduced.

Field data: The following graph shows the movement measure according to the trip purpose (BETUR, 2013) (Fig. 5).

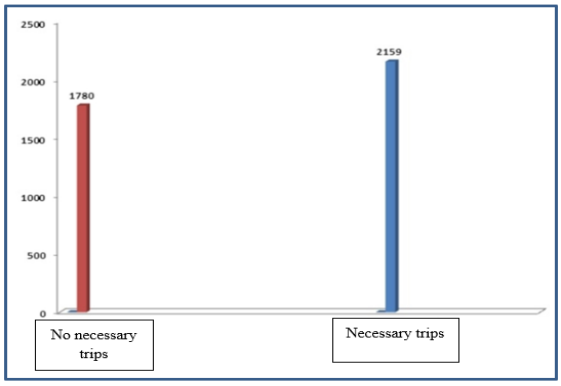

Fig. 5 – Movement measure according to trip purpose (BETUR, 2013).

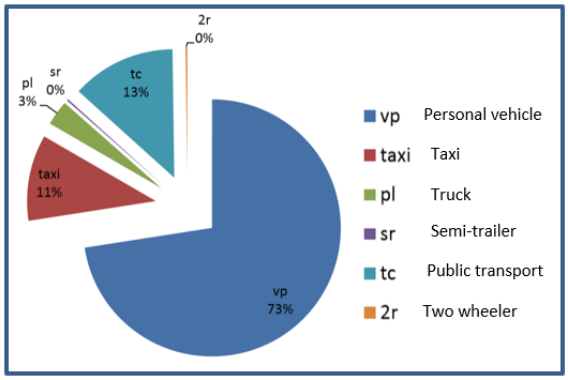

Fig. 6 – Modal distribution of daily traffic(BETUR, 2013).

The study states that 45.19% (1,780 travels) of trips are not necessary (shopping, visits, etc.) vs 54.81% (2,159 travels) of necessary trips (home-work, home-study, work-work, etc.).

Table 1

Modal distribution of daily traffic (BETUR, 2013)

Station	Direction	Personal vehicle	Taxi	Truck	Semi-trailer	Public transport	Two wheeler	Total
1	**1**	14,709	1,011	722	13	2,688	65	**19,207**
	2	12,411	1,445	494	8	2,112	51	**16,520**
2	**1**	10,596	1,457	234	33	1,076	48	**13,443**
	2	9,811	1,188	366	113	850	49	**12,377**
3	**1**	2,084	143	132	8	412	11	**2,789**
	2	2,631	168	152	0	496	11	**3,458**
4	**1**	7,627	2,298	360	5	1,392	0	**11,682**
	2	5,971	1,566	350	5	1,482	0	**9,374**
5	**1**	7,014	1,240	284	15	1,934	0	**10,887**
	2	6,355	1,306	334	23	1,830	0	**9,848**
Total	**1 & 2**	**79,209**	**11,822**	**3,428**	**220**	**14,272**	**234**	**10,9185**
		72.55	**10.83**	**3.14**	**0.20**	**13.07**	**0.21**	**100.00**

Table 1 and graph of Figure 6 above show that:

– The personal vehicle is throughout the most frequent mode, it reaching 79,209 vehicle unit, 72.55% of all the daily traffic.

– The daily flow of public transport, with a value of 14,272 vehicle unit, represents only 13.07% of all the traffic.

– The flow of two-wheeler has a small share and represents only 0.21% of all the traffic.

3.1.1. Abou Tachfine neighbourhood: road layout network

The Abou Tachfine District, located in the geometric center of the city, occupies a strategic area of the city, but very poorly connected with its environment (Figs. 7, 8 and 9). The structuring roads linking this district with the northern and southern parts of the city present problems related to their street layout. This does not structure the district and does not put it in connection with its environment. It is connected to the arterial roads of the city by two roads. The first one is wide and continues to its southern part, in opposite to its northern part, it is narrow, winding and steep (Figs. 10 and 11). The second is interrupted to the north and connected to an arterial street on the city's south side. This causes congestion during rush hours, observed on the ground, and displacement difficulties. There is a lack of a hierarchy of streets that causes a problem of localization and displacement; also no roads legibility (Figs. 12 & 13). It is causing saturation of the main roads with a poor accessibility to the neighbourhood, because the street layout of the neighbourhood does not offer multiple alternate roads.

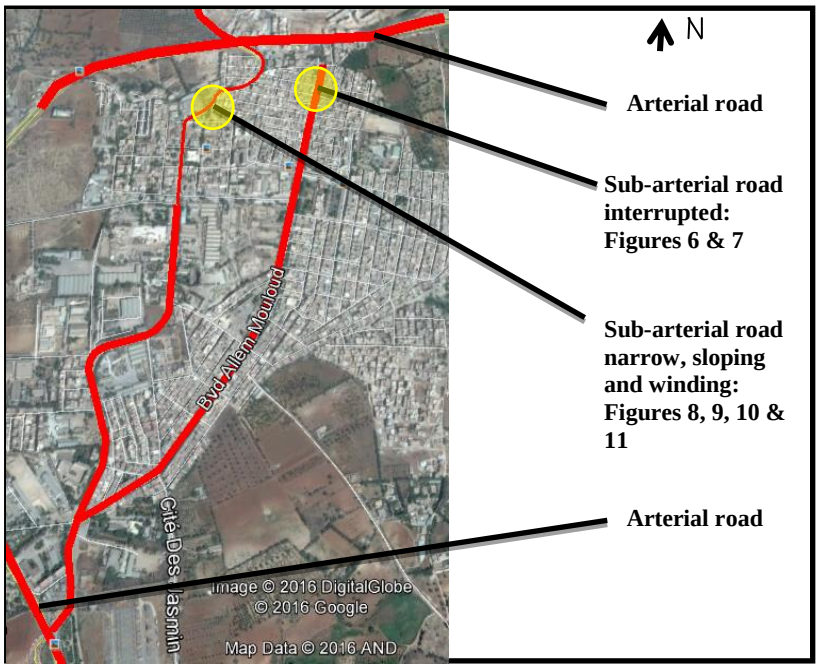

Fig. 7 – Arterial and sub-arteial roads connection of Aboutachfine neighbourhood.
Map produced on the basis of the aerial view 2016.

Fig. 8 – Sub-arterial road interrupted
(Djebbar, July 2018).

Fig. 9 – Sub-arterial road end
(Djebbar, July 2018).

Fig. 10 – Sub-arterial road narrow, sloping and winding (Djebbar, July 2018).

Fig. 11 – Sub-arterial road narrow, sloping and winding (Djebbar, July 2018).

Fig. 12 – Sub-arterial road: no legibility (Djebbar, July 2018).

Fig. 13 – Sub-arterial road: no legibility (Djebbar, July 2018).

3.1.2. Bouhanak neighbourhood: road layout network

Only two accesses connect the district of Bouhanak with the rest of the city from the main armature. It leads to a saturation of these nodes during rush hours. Additionally, several enclaves (student residence, university, residential areas for students, etc.) isolate Bouhanak neighbourhood to its immediate environment. The street distribution of the neighbourhood that should create consistency, continuity and connectivity between the various entities, is interrupted. Consequently, there is a juxtaposition of entities which leads to an urban disorder causing localization and displacement difficulties. This type of operation chosen for its simplicity, economy and rationality, no longer fulfils its role seen the multiplication of imperfections. This is the result of noncompliance of the street layout (Fig. 14).

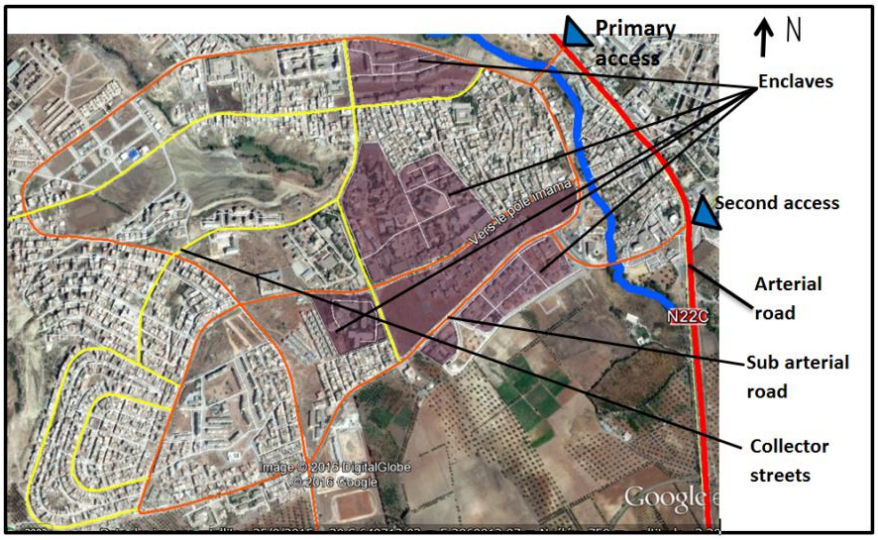

Fig. 14 – Arteriality and accessibility of Bouhanak neighbourhood.
Map produced on the basis of the aerial view 2016.

3.1.3. Dalias and Olives neighbourhoods: road layout network

Figure 15 show that the arterial roads with an important traffic present a rupture between the two districts: Dalias and Olives. This break is accentuated by the presence of a difference of topographical level, which completely isolates the neighbourhood of Olives from its environment. Several enclaves (barracks, student house, university, quoted residential, etc.) isolate Dalias neighbourhood to its immediate environment. Three accesses to the neighbourhood exist over a distance of 1,500 m, which leads to longer distances and reduced the access choice. The absence of a road hierarchy clearly expressed, despite the presence of an urban grid, makes its road layout be random, and it does not facilitate the drainage of flow by a connection between the roadways. This situation generates a saturation of the main roadways caused by the poor distribution of the flow and encourages the use of the car to the detriment of other travel modalities because the two districts are totally isolated.

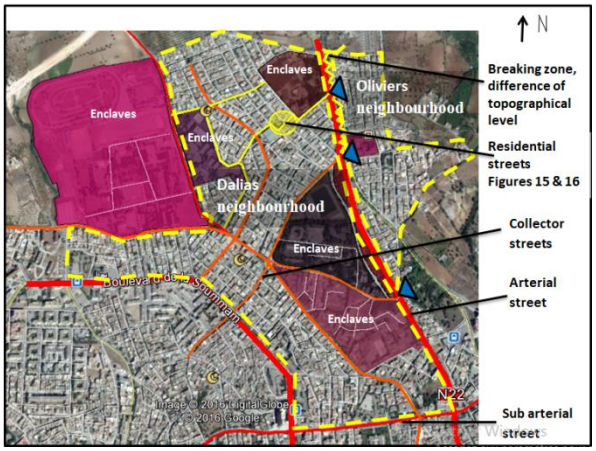

Fig. 15 – Arteriality and accessibility of Dahlias and Oliviers neighbourhoods. Map produced on the basis of the aerial view 2016.

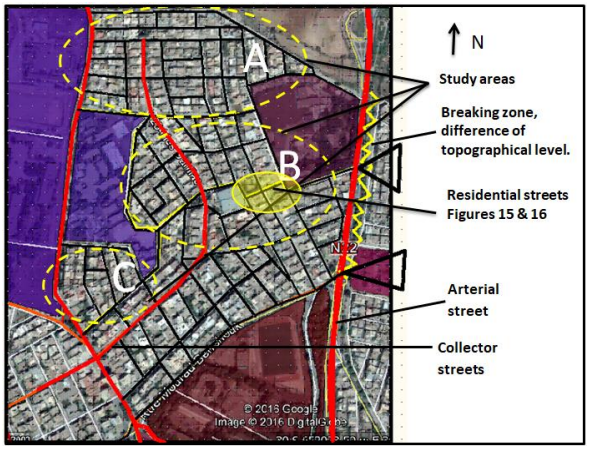

Fig. 16 – Study-areas and inner streets layout of North Dahlias neighbourhoods. Map produced on the basis of the aerial view 2016.

3.2. The internal roads of subdivisions

The street layout of the subdivision should in turn allow connectivity of the roads and different entity areas. By calculating the connectivity index, we will check the efficiency of the road network layout and whether this is sufficient for the proper operation of the neighbourhood.

3.2.1. The neighbourhood of Dahlias: road layout network

The first note is the absence of the street hierarchy. The arterial streets are not connected by secondary roads, ensuring continuity and tissue permeability (Fig. 16). We note, after the calculation of the connectivity index of residential streets, an acceptable index that approximates 1.40 (Figs. 17, 18 and 19). Despite these results, the district remains isolated from essential activity areas. The arterial roads are saturated because the district does not offer alternative travels to fluidify the flow. The first access road from the arterial road is broken, it is difficult to locate us to rejoin the collector street of the neighbourhood (Figs. 20 and 21). Legibility in the area is reduced, the streets do not allow the identification and the understanding of the structure for better use and enjoyment. Recourse to vehicle use is observed to travel to service areas and the trade of first necessities.

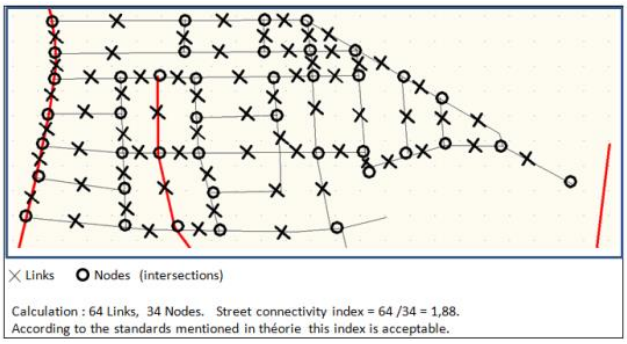

Fig. 17 – Calculation of connectivity index in North Dahlias neighbourhoods, area “A”.

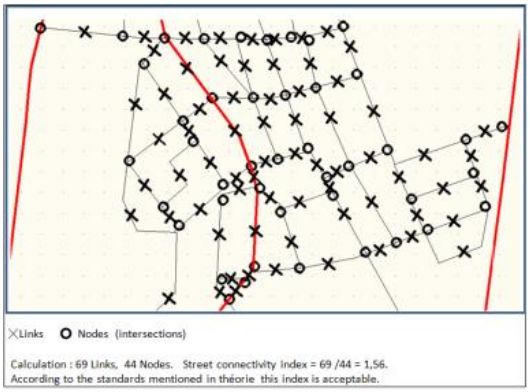

Fig. 18 – Calculation of connectivity index in North Dahlias neighbourhoods, area “B”.

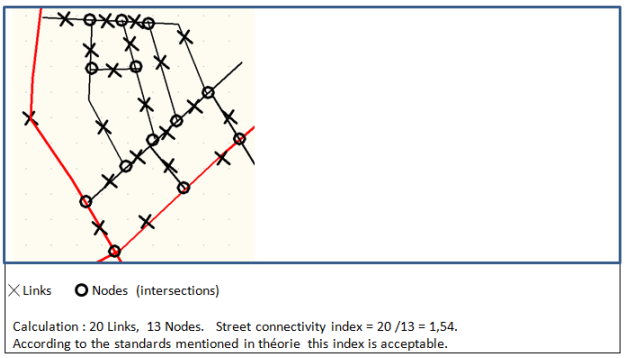

Fig. 19 – Calculation of connectivity index in North Dahlias neighbourhoods, area “C”.

Fig. 20 – No legibility and no imagibility (Djebbar, July 2018).

Fig. 21 – No legibility and no imagibility (Djebbar, July 2018).

3.2.2. The neighbourhood of Oliviers: road layout network

The street layout of this district is regular (Fig. 22), the connectivity index of local streets in the northern part of the district is 1.50, which is acceptable (Fig. 23). This area still remains isolated, the road forms a loop and is not connected to the main streets. This break is accentuated by the presence of a level difference between the area and the arterial road that already is an obstacle, given the large flow it serves. Consequently, residents are using the personal vehicle to go to service.

As for the southern part of the district, the area is isolated. The roads of section "A" form a loop and this section is not connected to its environment (Fig. 24). Section "B" is landlocked, despite the connection of its streets with the main routes (Fig. 24). It is located between an open field and a residential area with no activity. In addition, the connectivity index below the minimum allowed (1.34 and 1.26) (Figs 25 and 26) indicates poor connections of the inner streets.

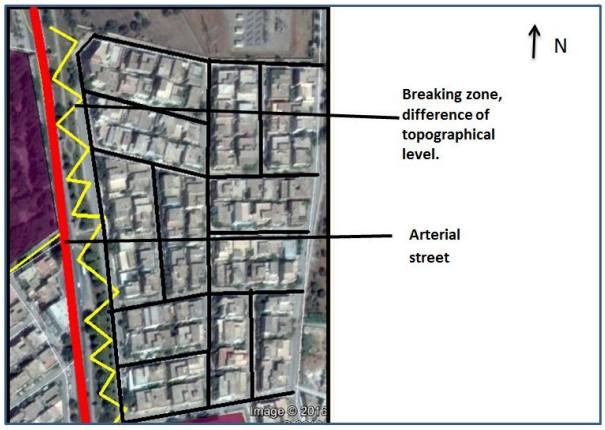

Fig. 22 – Inner streets layout of North Oliviers neighbourhoods. Map produced on the basis of Aerial view 2016.

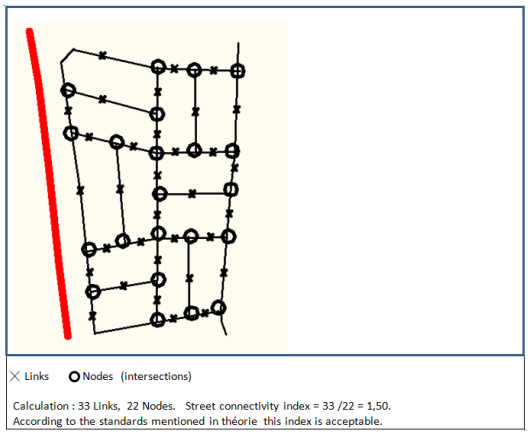

Fig. 23 – Calculation of connectivity index in North Oliviers neighbourhoods, area "B".

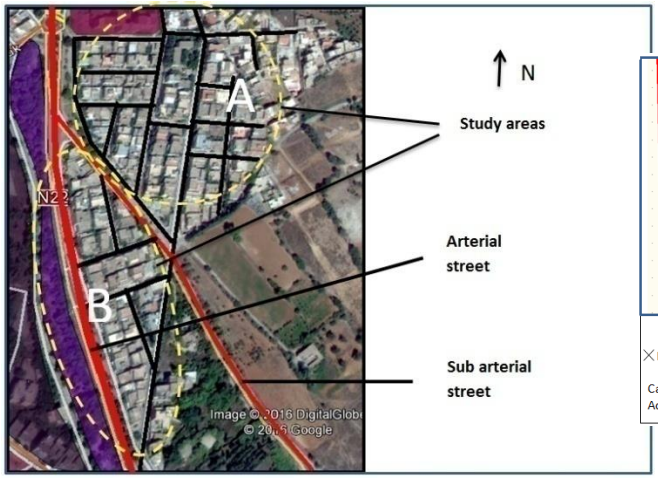

Fig. 24 – Study areas and inner streets layout of South Oliviers neighbourhoods. Map produced on the basis of the Aerial view 2016.

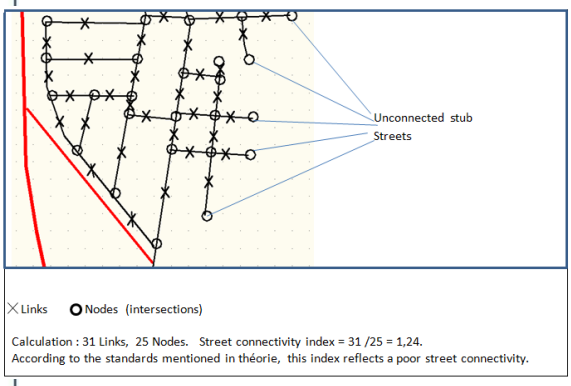

Fig. 25 – Calculation of connectivity index in South Oliviers neighbourhoods, area "A".

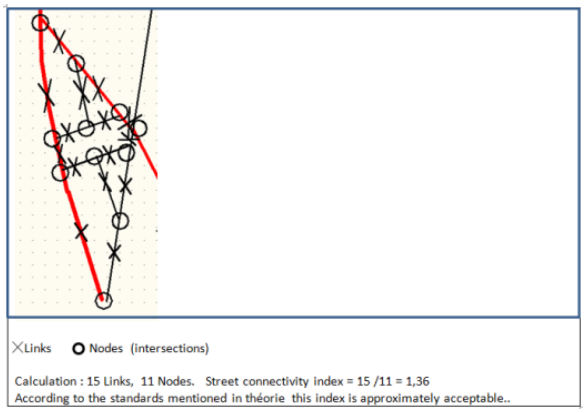

Fig. 26 – Calculation of connectivity index In South Oliviers neighbourhoods, area "B".

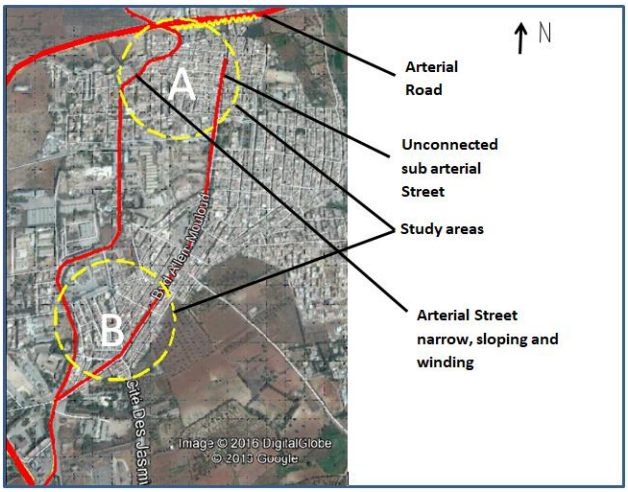

Fig. 27. Arterial roads and Study areas of Abou Tachfine neighbourhoods. Map produced on the basis of the Aerial view 2016.

3.2.3. The neighbourhood of AbouTachfine: road layout network

The absence of a hierarchy of roads and the discontinuity of the central main street are observed. It is leading to the saturation of the only access road to the area from the north (Fig. 27). The latter, being narrow and winding, leads to traffic saturation at the intersection with the main artery of the city. This street layout is not hierarchical, it offers no alternative to drivers to use alternate routes to thin the stream (Figs. 28 & 29). However, the connectivity index of local streets is acceptable (Figs. 30 and 31), the streets are well connected.

Fig. 28 – Inner streets layout of Abou Tachfine neighbourhoods, area “A”.
Map produced on the basis of the Aerial view 2016.

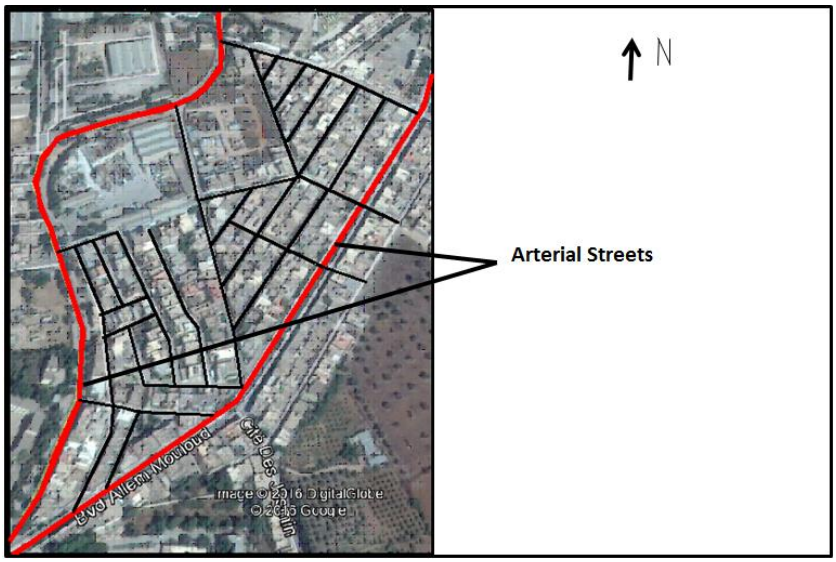

Fig. 29 – Inner streets layout of Abou Tachfine neighbourhoods, area “B”.
Map produced on the basis of the Aerial view 2016.

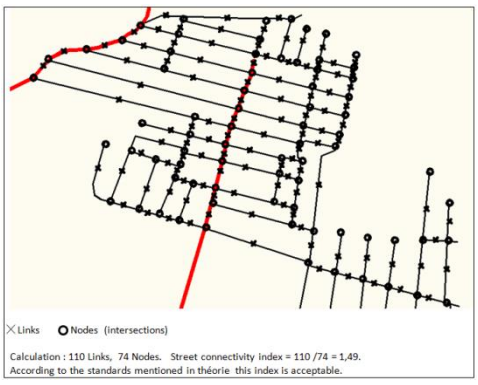

Fig. 30 – Calculation of connectivity index in Abou Tachfine neighbourhoods, area “A”.

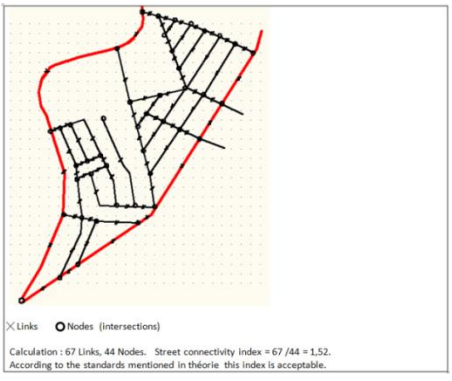

Fig. 31. Calculation of connectivity index. Abou Tachfine neighbourhoods, area “B”.

4. DISCUSSION

The structuring roads of Tlemcen city do not cross the group but bypass it. This involves a problem of subdivision accessibility which is not done directly from the continuous road to the urban centers. These various bypass and break of access roads to subdivisions and with the absence, in most cases, of a road hierarchy clearly expressed and roads ligibility create difficulties of localization and imply longer distances to make in these groupings. It implies difficulties to identify the shortest street between different points of the subdivision. In addition, it encourages the use of the car rather than other travel modalities since the district is isolated.

The study results of the different neighbourhoods also reveal that the main roads do not structure the district and does not put it in connection with its environment. This causes congestion during rush-hours observed on the ground and displacement difficulties. It is causing saturation of the main roads with a poor accessibility to the neighbourhood, because the street layout of the district does not offer multiple alternate roads. Additionally, several enclaves generally isolate the subdivision to its immediate environment. The street distribution of the neighbourhood that should create consistency, continuity and connectivity between the various entities, is interrupted. Consequently, there is a juxtaposition of entities which leads to an urban disorder causing localization and displacement difficulties. This type of operation chosen for its simplicity, economy and rationality, no longer fulfils its role given the multiplication of imperfections. This is the result of non compliance of the street layout.

The connectivity index of inner streets indicates acceptable average values. In return, we note the absence of the street hierarchy clearly expressed and the roads ligibility. Also, we observe a poor accessibility to the neighbourhood. Despite these results, the district remains isolated from essential activities areas. The arterial roads are saturated because the district does not offer alternative travels to fluidify the flow. Generally, the arterial streets are not connected by secondary roads, ensuring continuity and tissue permeability. Legibility in the area is reduced, the streets do not allow the identification and understanding of the structure for better use and enjoyment. The recourse to vehicle use is made to travel to service areas and of first necessities trading.

4.1. Synthesis

In Table 2, we observe that the calculation of the connectivity index indicates acceptable average values. The other conditions of functioning (Continuity of main Roads, Legibility of street layout, roads hierarchy, Accessibility and Mobility) are not met, several deficiencies are noted. This led to the saturation of the main streets and the systematic use of the car in all the studied cases.

Table 2

Recapitulative table

Subdivision	Connectivity index of inner Streets	Continuity of main Roads	Legibility of street layout	Road hierarchy	Accessibility	Mobility
Dahlias Area A Area B Area C	 1.88 1.56 1.54	Bad	Bad	Bad	Low	– Saturation of the main roads. – Using the car.
North Oliviers	1.50	Bad	Bad	Bad	Low	– Saturation of the main roads. – Using the car.
South Oliviers Area A Area B	 1.24 1.36	Bad	Bad	Bad	Low	– Saturation of the main roads. – Using the car.

Table 2 (continued)

Aboutechfine Area A Area B	 1.49 1.52	Bad	Bad	Bad	Low	– Saturation of the main roads. – Using the car.
Bouhanak	The subdivisions of this neighbourhood are unfinished. So we could not calculate the connectivity index. The observation was made only for the main network of the city.	Bad	Bad	Bad	Low	– Saturation of the main roads. – Using the car.

5. CONCLUSIONS

Finally, good connectivity does not stop in domestic routes of the subdivision, but must extend beyond for ensuring the continuity and harmony between all entities in the built-up environment. The main road network of the city must additionally play its role in connecting the subdivision with its environment.

The theoretical approach has enabled us to highlight the importance of the street layout in the overall organization of subdivisions and their connectivity. It was a two-scale study. The first scale concerns the main road network of the city. It reveals its role and how it links the subdivision with its environment. Simplicity and regularity in favour of the economy are principle criteria used in the subdivision operation. The various subdivisions are structured by the city's road network. It connects them and determines their morphology. It is from these primary roads that initiated the internal hierarchy of the road. They extend from one neighbourhood to another for the purpose of overall consistency. This creates good connectivity between different entities. By comparing these results with the subdivision operation at Tlemcen, it proved a failure to comply with conceptual rules linking the main street layout of the town. In addition, the internal layout of the subdivision caused low accessibility of subdivisions and poor road connection. Through the examples studied, the road network does not play this essential role of linking subdivisions with their environment ensured by good road connectivity. This explains many failures observed, which are caused by poor accessibility of subdivisions with its inner distribution which does not link them. These failures and the low number of access to urban groups are the cause of the saturation of some roads. The poor connectivity of the main roads, reduces are alternate road for automobiles and roadways options for the other travel modalities. The second scale relating to the internal roads network of the subdivision was explored. This shows the organization impact, of the internal road network of subdivisions and its connectivity, on functioning (mobility, accessibility, etc.). In the subdivision, street connectivity, their hierarchy clearly expressed and the permeability of tissues are identified criteria of the theoretical approach. The regularity of urban plans, the rationality and the simplicity of the street layout are characteristics of the urban fabric of these subdivisions, they promoting street connectivity. This criterion encourages the functional diversification and the complexity lacked by old urban fabrics. Good legibility of the road network and connectivity of routes, facilitate travels and communications between different areas of activity. This promotes walking and reduces the distance travelled by different trip ways. This street layout preserves the health of individuals, encouraging pedestrian traffic and offering more choices for culinary services to users. A decrease in the saturation of some roads is promoted by the use of a well-served existing network. These criteria are the condition for the proper functioning of the entity. These elements allow the fabric to evolve and become more complex and able to respond to possible new needs.

The importance of the street layout in the overall organization of subdivisions and their internal distribution is highlighted in this work. Comparing these results with the production of subdivisions in Tlemcen City proved non-compliance with conceptual rules and procedures that put the relationship of the city street layout and the interior layout of the subdivision. In the examples studied, the street network does not play this essential role of fabric linking and permeability. Generally, the calculation of the connectivity index indicates acceptable average values. Although the other conditions of functioning were not met, several deficiencies are noted. First, the saturation of some roads is observed, induced by the low number of access to urban groups. Second, the route offers few options to drivers to use alternate routes to reduce the flow. Also, this failure is affected by the difficulty of identifying and moving from one point to another. This is due to the presence of many bends in the paths, and lengthening their distances. In addition, one can say that those difficulties in the movement of individuals and the systematic use of the car are prejudicial to the environment and to the public health.

For a better connectivity of the road network in the subdivision, the main street layout of the city must organize the subdivision. The inner streets must be well-linked to the main network of the city from which they are hierarchical. Several accesses should be provided, as well as a good legibility of the network. The connectivity index must be higher than 1.4 and the blocks most often between 100 m and 200 m.

Our contribution illuminates the designers and policy makers on the importance of the arterial street network layout in linking different subdivisions and the overall consistency in the city. In addition, connectivity increases the number of access to different urban groups and relieves pressure on the arteries in thinning the traffic flow. This additionally encourages alternative modes of travel. However, to complete this work, other factors should be studied: density of the road network, population density and streets dimensions (track widths, sidewalk widths).

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