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MEASURING PUBLIC TRANSPORT ACCESSIBILITY IN CASABLANCA ACCORDING TO UNITED NATIONS SUSTAINABLE DEVELOPMENT GOALS USING A GEOGRAPHICAL INFORMATION SYSTEM

ELHASSAN ELBRIRCHI[1], ISHAK HBIAK[2]

[1,2]Geomatics Sciences Research Team (SGEO), Hassania School of Public Works (EHTP), Morocco

E-mail : [1]hbrirchi@gmail.com, [2]ishak.hbiak@gmail.com

ABSTRACT

Casablanca is the biggest city in Morocco. it contains 40 % of national mobility. Thus, accessibility to public transport network is a key factor for the development of the city. It is also very crucial to maintain a minimum quality of transportation services over time. United Nation Sustainable Development Goals (SDG), adopted in September 2015, highlight the importance of urban transport accessibility in goal number 11 and propose the indicator number 11.2.1 to monitor the accessibility to services, goods and opportunities for all. The objective of this research is to estimate this indicator value for Casablanca city center and surrounding provinces: Mohammadia, Mediouna and Nouaceur. This research thus contributes to the efforts to implement the objectives of the 2030 Agenda in Morocco, particularly concerning urban transport. We also seek to compare results for different public transport modes available in the city, namely the tram and the bus. To achieve these goals, we first propose an adapted methodology based on the metadata of the SDG indicator 11.2.1. To do this, we have created a Geographic Information System (GIS) database containing needed data such as administrative districts, urban roads, bus network lines, tram lines and population statistics. As a result, we found that 74,38% of the population in all our study area has access to bus network while 95.51% of the population of the center has access to bus and tram networks. The detailed results by sector highlight the imbalance in the access to transport between the city center and the surrounding areas.

Keywords: *Urban Transport, Sustainable Development Goals, Accessibility, Geographic Information Systems, Casablanca*

1. INTRODUCTION

1.1. Urban Planning and GIS

In recent years, urban planning has regained importance, especially for large cities. The perception of design and its purposes change from time to time, this evolution since the last century is traced in [1]. The design of modern cities deals with many challenges from an organizational, social, economic, environmental and technical point of view, which denotes of the permanent complexity of this task. The thinking in urban planning should then be resilient [2].

Fortunately, the significant development of technologies allows decision-makers and planners to complete this task. It also enables the implementation of dynamic and participatory planning approaches. Several researches illustrate the use of new technologies to support the resolution of urban problems related to the energy supply, the environment, the consideration of climate change, the technical management of urban infrastructures or the assessment of education facilities offer in urban area as shown in [3], [4], [5], [6] and [7].

The urban planning process mainly uses geospatial information. The use of Geographic Information System (GIS) is therefore essential to support all the stages of such a process. According to [8], the increasing use of GIS in urban planning and design holds the promise of enabling a higher quality of quantitative and qualitative data analysis, thereby improving the evidence base of decision-making as well as the knowledge base of the decision-making process.

The late developments of GIS techniques now allow a significant use of information technologies, whether during the acquisition phases

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or during the analysis and sharing phases of a GIS project. This technical fact opens up new prospects for planning and city management. For example, [9] propose a platform combining GPS traces and big data analysis to analyze and monitor buses activity in global events.

The quality of geospatial data plays a key role to the success of GIS analysis. This quality depends on many criteria including geometric precision, update frequency and completeness. These data are available and accessible to GIS users or developers through standardization efforts and investments in land mapping made by central or local governments.

The use of information technologies facilitates the sharing of spatial databases through geoportals and data catalogs. However, this data infrastructure is weak in developing countries, which is usually a limiting factor to the implementation of GIS solutions.

Given these well-known constraints in cities in developing countries, the design of a spatial data infrastructure adapted to this context constitutes a challenge and an important contribution to facilitate the calculation, processing, analysis and monitoring of SDG indicators. Mounting of GIS solutions would be easier with the existence of such an infrastructure once in place.

Otherwise, we would have to face classic difficulties such as converting between spatial data formats, updating the spatial database, setting up the necessary data and pre-processing the spatial data in a GIS environment or even construction of a GIS network to allow analysis based on graph theory algorithms.

Having such an infrastructure in a city facilitates and enhances the capabilities of sharing data and knowledge derived from GIS analysis so that we can save a lot of time for local decision makers

1.2. Urban Planning and Transport

Urban planning is strongly determined by the urban transport system in place. According to [10], land use-transport interaction has wide and diverse inter-dependences and it is an issue that has remained on the table for decades. Integrated transportation and land use planning is aimed at allocating land to different groups in society and for societal activities [11].

In addition, the urban form strongly influences the needs and practices of transport in cities, the consequence on the transport system is very different depending on whether it is a sprawl or a compact development of the city. A detailed focus on this relationship is given by [12].

As with most urban planning issues, GIS remain an essential technological tool for the planning, design, operation, monitoring and analysis of urban transport systems. Indeed, as shown in [13], GIS will facilitate integration with the transport network database of all other socio-economic data for the diverse planning functions.

1.3. Contribution And Objectives of This Research

The question of sustainable development arises in Morocco. Our country is also involved in international efforts and agreements supporting this issue, in particular the United Nations 2030 Agenda.

The research efforts as proposed in this paper will contribute to satisfying the need for indicators of global strategic orientation and more specifically in urban transport. These kinds of researches will make it possible, among other things, to propose, test and adapt methodologies for calculating, monitoring and analyzing these indicators. Officials could fulfill their commitments more simply and more efficiently.

Otherwise, several elements in the context of the city of Casablanca convinced us of the need to carry out our research idea. Indeed, since the achievement of the local urban transport plan for Casablanca in 2007, this city has experienced a very strong dynamic of change in urban transport.

In November 2019, the city's local authorities decided to introduce a new Bus transport operator. A restructuring of the Bus network has also taken place. In addition, the recommendations of the local urban transport plan continue to be implemented with the launch of the second tram line in January 2019. Currently, other projects are also in progress.

All these recent and important changes in the public transport offer in Casablanca, justify the need to evaluate them on the basis of adapted indicators

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Regarding the objectives of this research, the main objective of this research is to estimate public transport accessibility for the city of Casablanca and its close peripheral area, in Morocco. This measure is done according to United Nations Sustainable Development Goals (SDG) specifically goal number 11 about making cities and human settlements inclusive, safe, resilient and sustainable.

In our previous work [14] we have defined some indicators to study mobility in Casablanca in relation to sustainable development. In this research, we focused specifically on the evaluation of the accessibility of public transport according to the definition of the United Nations 2030 agenda.

The more specific objectives are to use GIS and collect a geodatabase to assess accessibility for public transport as a first step. Afterwards, analyze the contribution of new tramway infrastructures compared to conventional bus transport in Casablanca.

2. URBAN TRANSPORT ACCESSIBILITY

Urban transport planning and design deals with several parameters such as supply, demand, infrastructure, institutional organization, environmental issue and sustainable development concerns. The accessibility to public transport also remains among the key factors of this kind of studies.

On the whole, a variety of methods has been developed for measuring accessibility, based on different kinds of dataset and using various types of metrics and indices [15]. Distance, time, cost, transport mode, quality of service and activity are key parameters for estimating and analyzing the accessibility of a transport network.

The measure of accessibility can be applied to several urban services in cities: health [16], schools [17], [18] public parks [19] or jobs [20]. It thus provides a fairly precise idea of the relevance of urban planning in cities as well as of social inequalities in terms of access to opportunities and services.

The dynamic measurement of accessibility or at least the continuous one's of this parameter allows the monitoring and the correction of urban governance actions. According to [21], quantitative assessment of the impact of traffic accessibility in large cities even influences innovation, leading to a better understanding of urban governance and sustainable development.

The measurement of accessibility is therefore clearly a complex and very data-intensive subject. The availability of these data in developed countries is well assured, whether it is proprietary data provided by local authorities or whether it is open data.

On the other hand, developing countries suffer from the lack of these data and also from the lack of quality when they are available. In order to be able to generalize the calculation process, it is therefore very important to propose an accessibility indicator that is as simple as possible. Moreover, for considerations related to global sustainable development, such an approach may be sufficient.

3. SUSTAINABLE DEVELOPMENT GOALS

In September 2015, United Nations adopted the resolution 70/1 in its General Assembly about “Transforming our world: the 2030 Agenda for Sustainable Development” with the main objective of acting against poverty and hunger. This resolution defines 17 Sustainable Development Goals and 169 targets. This resolution aims also to create conditions for sustainable, inclusive and sustained economic growth, shared prosperity and decent work for all, taking into account different levels of national development and capacities [22]. Later in 2017, another adopted resolution, 71/313, by the United Nations defined “The global indicator framework” to help the implementation of the 2030 Agenda [23].

Achieving the goals within the designated timeframe, however, entails overcoming multiple challenges related to policy design, resources management, and harnessing the synergies and trade-offs among the goals themselves [24].

As shown in [22], the SDG goal 11 is about to make cities and human settlements inclusive, safe, resilient and sustainable where the SDG target 11.2 is about to provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons. In summary SDG goal 11 is about

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urbanization while target 11.2 is related to urban transport.

The global indicator framework [23], define indicator 11.2.1 as the proportion of population that has convenient access to public transport, by sex, age and persons with disabilities. To measure the progress towards achieving SDG Target 11.2, cities are to measure the proportion of the population within 500 m of a public transport system [25].

One of the most important areas of sustainable development is transport sector [26]. Indeed, there is no absolute consensus on the definition of sustainable development and no longer on that of sustainable transport. That said, we limit our research to the approach proposed by the United Nations resolution on the SDGs.

Finally, it should be noted that the GIS in a same way as others information technologies, plays as specified by [27], an important role in the monitoring of the SDG indicators and the achievement of its objectives.

At the end of this section, we would like to highlight the main questions we want to address through this research.

Indeed, following the problem of availability and quality of data mentioned in the previous section 2, Casablanca presents a particular context characterized by the absence of a spatial data infrastructure which implies problems of lack of data, sharing and updating as well as spatial data governance issues.

The calculation of the accessibility indicator must therefore follow an approach adapted to this context. The first problem to be addressed in this research will be to propose an appropriate methodology for calculating the SDG indicator 11.2.1

The reuse of this method is important to ensure continuity in the measurement of this indicator. The proposed method should therefore be simple, feasible and reusable as much as possible.

The calculation of the indicator of accessibility to public transport services during this period will also make it possible to evaluate the effect of the actions taken recently by the local authorities of Casablanca.

Finally, another problem to be clarified in this research consists in evaluating the equitability in terms of accessibility between the populations in the center and those of the periphery.

4. STUDY AREA

4.1. Demographic and Socioeconomic Data of Casablanca

Our research is focused on the area of the central city of Casablanca as well as its surrounding peripheral provinces. Casablanca is the unchallenged linchpin for Morocco’s economy [28]. According to the local investment authority, the share of national GDP for the Casablanca-Settat region is around 32.2%. It also contains 69% of Morocco's foreign trade and 40% of national mobility.

Casablanca has expanded around its port which was built at the beginning of the 20th century. The economic development of the city has attracted several migrants and continues to do so. The population of the central city of Casablanca, outside its peripheral provinces, has thus increased from a few hundred at the very beginning of the 19th century to 3,350,912 in 2014 and estimated at 3,619,934 in 2022. figure 1 shows a map of our study area as specified above. It shows also the decomposition of the total population (green color) between urban (grey color) and rural (brown color).

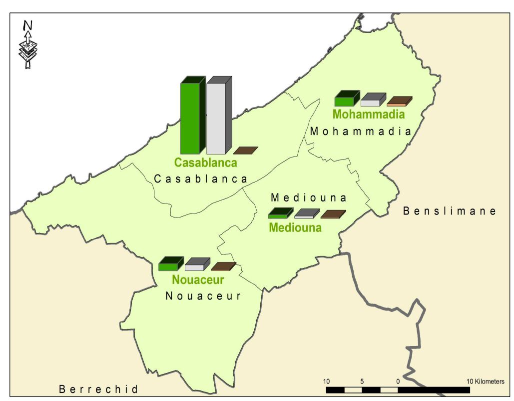

Figure 1: Study Area: Casablanca and its Immediate Peripheral Provinces

Although the large part of the population is within the various districts of the central city, the peripheral provinces of Mohammadia, Mediouna and Nouaceur are experiencing, on the other hand, a strong urban extension and an increase in their urban populations.

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Table 1: Study Area Population Data From Household Population Census

	Province	2014 (census data)			2022 (Estimated data)		
		Total Population	***Urban Population***	***Rural Population***	***Total Population***	***Urban Population***	***Rural Population***
Central city	Casablanca	3350912	3350912	0	3619934	3619934	0
Peripheral Provinces	Médiouna	170905	118503	52402	271710	208801	62909
	Mohammadia	403222	287844	115378	458314	332984	125330
	Nouaceur	330056	274890	55166	527558	461838	65720
	Total Peripheral Provinces	904183	681237	222946	1257582	1003623	253959
Total Study Area		4255095	4032149	222946	4877516	4623557	253959

The last general population census took place in Morocco in 2014, the next one is scheduled for 2024. According to the Moroccan census administration [25], the highest average annual population growth rate, between 2014 and 2030, of the entire Casablanca-Settat region, is recorded in the provinces of Mediouna: 5.85% and Nouaceur: 5.78%. table 1 presents the details of the population census data related to our study area according to [29], whether for the 2014 census data or for the 2022 projected population data.

Regarding employment in our study area, the net activity rate varies slightly around 50% while the unemployment rate varies between 12.6% in Nouaceur and 18.9% in central city of Casablanca, according to the published data by Moroccan census administration. These activities are linked to several sectors among which we find mainly, services, construction, industry, tourism, fishing and logistics. In addition, the main headquarters of the stock exchange, banks, insurance companies as well as major national and international groups are located in Casablanca.

4.2. Urban Transport in Casablanca

According to Casablanca's local urban transport plan of 2007, public transport represented 13% of total trips, private car mode 14.5% and taxis 15.5%, while walking mode represented 53% of a total of 11 million trips. These results are based on several surveys, the main one being a household travel survey carried out in 2004.

As the modal part of public transport is very low, several recommendations have been made to improve it, mainly the introduction of public transport rail networks (metro and tram) and Bus Rapid Transit (BRT) proper lines. Another important recommendation concerned the reorganization of the BUS network.

Today, the public transport offer consists of the classic bus network in addition to rail network composed of two tram lines named T1 and T2.

The first tram line, 24 km long, was launched on December 12, 2012, while the second, 23 km long, was put into service on January 23, 2019. Regarding the bus network, a new operator was introduced in 2019. The bus fleet is estimated at 700 buses running on around fifty BUS lines.

By 2024, two other tram lines named T3 and T4, currently under construction, will be operational. According to the local authorities in charge of the project, the progress is estimated today at 70%. The lengths of these two lines are 14 km and 12 km respectively.

In addition, two BRT lines named BW1 and BW2 are also under construction. Their lengths are 12.5 km and 12 km respectively. We note that an indicator system for evaluation of BRT operation is given by [30].

Including these future lines, the total offer of tram and BRT lines will be estimated at nearly 100 km.

5. MATERIALS AND METHODS

5.1. Collected Data

In order to be able to calculate our accessibility indicator we need to collect the

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following data for the entire city of Casablanca and its immediate peripheral area: Administrative Districts, Urban Roads, Bus network, Tram lines and population statistics from the general population census.

In figure 2 we see the road network of Casablanca and its neighboring provinces of Mohammadia, Mediouna and Nouaceur. In sum, nearly 6800 km of roads, most of which in the central city of Casablanca. The density of roads is lower in the outlying provinces as they are in recent urban expansion phases.

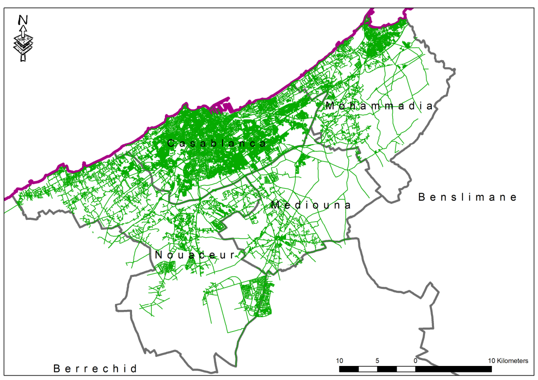

Figure 2: Casablanca and its Peripheral, Urban Streets

Map in figure 3 shows the 962 bus stops in our study area, which correspond to both outward and return directions. These stops relate to 54 bus lines. It appears from the map that the service in the peripheral areas is less important than in the city center of Casablanca.

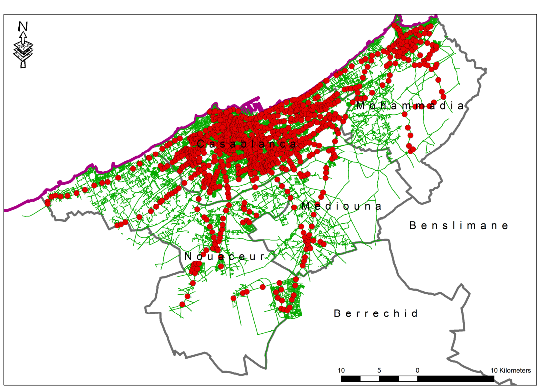

Figure 3: Casablanca and its Peripheral, Bus Stops

Finally, figure 4 shows the route of the two tram lines named T1 and T2 as well as their 131 tram stops. The tram rail network is however limited to the central city of Casablanca. For the moment, it is not yet planned to extend it to peripheral areas.

Our indicator needs also population data to estimate accessibility. We used data from the official household population census carried out in 2014. As in Morocco, this survey takes place every ten years, the next one is scheduled for 2024. As we are now eight years away from the last census, we have used corrected population data with projection to 2022 given by the census administration.

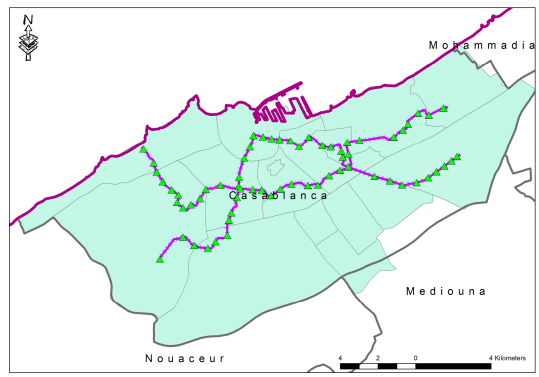

Figure 4: Casablanca T1 and T2 Tram Lines and Their Stops

5.2. Adapted Methodology to Estimate SDG Indicator 11.2.1

The particular context of our study area with regard to the availability of data, their quality, their updating as well as data sharing policies led us to work on an adapted methodology compared to that proposed through the documentation of SDG indicators.

According to SDG indicator 11.2.1, accessibility is measured by considering only the spatial parameter, which is recognized as relevant and sufficient to track the indicator in a given area over time.

According to the metadata of the indicator, it is important to start with the delimitation of the urban space. For our case study, the central city of Casablanca contains no rural population and concentrates 79% of the overall population of our study area. For the peripheral provinces, 75% of their population is also urban. In the end, 95% of the population of our study area is urban. We have therefore decided to adopt the administrative division as the delimitation of the area of analysis. It should also be noted that the bus lines of the

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outlying provinces are essentially accompanying urbanization operations.

Furthermore, the proposed methodology distinguishes between a low-capacity public transport system such as bus, tram and BRT and a high-capacity transport system such as metro. for the first case the analysis distance is 500 m and for the second case the proposed distance is 1000 m. As in Casablanca there is the Bus network and the tram network, while in the peripheral areas there is only the Bus network, we will adopt the distance of 500 m only for our analysis. It should be clarified that this distance is considered as a walking distance to the nearest transport stop according to the road network

To calculate the distance according to a road network it is necessary to have good quality road data. Given the data available, it was necessary to carry out a pre-processing which consists of correcting certain lines after a topological analysis in GIS environment. One of the major problems was also the updating of road data: it was necessary to digitize the urban roads corresponding to recent urban construction operations, particularly in peripheral areas. To perform this task, we have used remote sensing data services available through the GIS environment.

Furthermore, the proposed methodology recommends the use of high-resolution demographic data collected by national statistical institutes. These data, even if it exists, are not shared publicly. The finest distribution available for our research corresponds to 2400 sectors with an average population per sector of 1675 inhabitants. The average area of the sectors is 480,000 m2 with a minimum of 5,500 m2. Moreover, the characteristics of the sectors in terms of area and population are not homogeneous. We then proposed in a very simple approach, to take the population living in the intersection area between the sectors and the analysis zone. This population data is estimated with the assumption of a homogeneous population density. Sectors size are much small in Casablanca central city. They are then more compatible with the analysis size around stops. However, as their sizes are bigger than the analysis one in the outlying districts this problem arises in these peripheral districts and it is very low in Casablanca central city. Consequently, the adapted methodology adopted for our research, is as follows:

1) Definition of the administrative boundaries of the study area.
2) Inventory of public transport stops:
    a) Integrate the GJSON file of the BUS network into the Geodatabase
    b) Download tram network data from Open Street MAP (considered more up-to-date in this case)
3) Urban road network pre-processing:
    a) Updating the network by digitizing missing parts from very high-resolution satellite images using a remote sensing image service in a GIS environment
    b) Correction and topological analysis
4) Build the network from simple GIS data using an ESRI geometric network
5) Analysis of the constructed network by creating an aggregated area corresponding to a 500 m walk to the nearest public transport stop.
6) Compute the estimated population
    a) Intersection between the generated analysis area and the demographic statistics data sectors.
    b) Calculation of the ratio of population in the intersected sectors using the surface ratio.
    c) Estimated population within walking distance of public transport
7) Estimated proportion of population with convenient access to total city population.

6. RESULTS AND DISCUSSION

6.1. Grouped Geodatabase

All collected data are consolidated into a geodatabase to facilitate GIS analysis. This database contains as specified above:

- ✓ All of the administrative divisions with statistical population data down to the level of available low demographic resolution sectors, needed for spatial analysis.
- ✓ The completed and cleaned urban road network as well as the generated geometric network
- ✓ All bus and tram stop
- ✓ The very high-resolution satellite image available from the GIS service

This geodatabase could be very helpful to perform future analysis as the indicator should be monitored over time.

6.2. Public BUS Network Accessibility

Following our adapted methodology, we started by calculating the accessibility of the Bus public transport network in our study area. Map in figure 5 shows the buffer zone of the service area corresponding to a walking distance of 500 m through the road network to the bus stops.

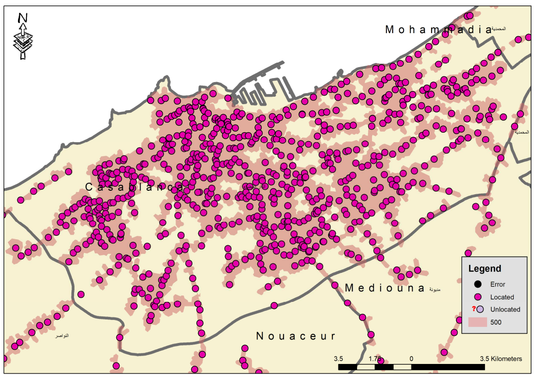

Figure 5: 500 m Service Area Buffer Related to Bus Stop

Without taking into account population statistics, it is clear from this map that accessibility decreases from the center to the periphery. It can be seen that the service of public transport by bus concerns mainly new urbanized areas in peripheral provinces. This result prompts us to ask ourselves the question of the role of urban transport in stimulating urbanization and not the reverse.

The results of the calculation of the SDG indicator 11.2.1 are presented in table 2. These results confirm the purely spatial observation done above.

Table 2: SDG Indicator 11.2.1 For BUS Public Transport

Province	SDG Indicator 11.2.1 value
Casablanca city	84.28 %
Mohammadia	64.45 %
Mediouna	40,47 %
Nouaceur	34.77 %
Total Study Area	74.38%

We would like to mention here again, as specified above, that the accessibility indicator only takes into account the spatial parameter, by applying a buffer analysis of 500 m of walking distance and that the calculation is also done under the assumption of a homogeneous distribution of the population.

6.3. Tramway Accessibility

In the next phase of our analysis, we redid the calculation for the tram network. Map in figure 6 Shows the 500 m walkable service area around the tram stops. We notice that without a significant ramification of the tram network the accessible area remains small. It is therefore important in the case of Casablanca to consider the complementarity between the bus and tram public transport modes, in order to improve the accessibility parameter.

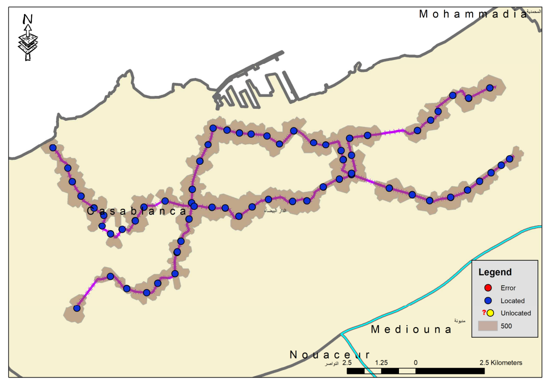

Figure 6: 500 m Service Area Buffer Related to Tram Stop

Hence, we redid the calculation of our indicator including the bus and tram stops. Map in figure 7 shows the result obtained.

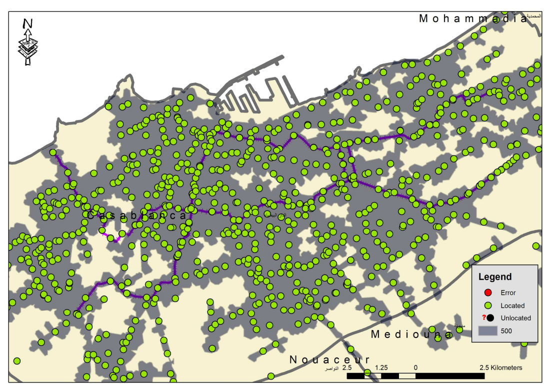

Figure 7: 500 m Service Area Buffer Related to Tram and Bus Stop

The results of the calculation of the SDG indicator 11.2.1 related to tram mode and to tram and Bus mode for the central city of Casablanca are presented in table 3. These results confirm the key role of integration between urban transport mode.

We note also an enhancement of accessibility by 11 % in central city of Casablanca as a consequence of introducing tramway network.

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Table 3: SDG Indicator 11.2.1 in Central City of Casablanca for Tram and Bus Public Transport Mode

Public Transport Mode	SDG indicator 11.2.1 value
Tram	20.57 %
Tram and Bus	95.51 %

These results, even realistic, can be improved in terms of accuracy by improving the input data to our calculation process. Accessing disaggregated data from the general population census, taking into account of the road network updates, particularly in connection with new urban extension projects or consideration of the geolocation of urban activities and residential areas can certainly improve the calculation model.

Indeed, it should be noted at the end as limits of this result that the SDG indicator 11.2.1 in addition to the calculation done of accessibility to public transport networks, also aims to break down this result according to age and sex. However, this demographic information is not available at high resolution at the sector level, it is only aggregated at lower resolution, so we were unable to provide this information by age and sex.

On the other hand, it is also very important to maintain the simplicity and feasibility of this methodology in order to be able to generalize it to other cities and other developing countries.

Regarding some points presented in the literature section we note that the accessibility indicator is a consequence of urban planning effort and its effective implementation. The calculation of spatial accessibility prompts more research to understand the results obtained by further analyzing other social, economic, technical or environmental parameters.

In addition, maps clearly show the relationship between transport and urban planning. Indeed, the concentric and radial urban form of the city of Casablanca, around its Port, is well illustrated in the results obtained. Starting from the center towards the periphery areas the estimated accessibility is higher in the central areas, which are also the oldest, unlike the lower values obtained on the periphery where urbanization is more recent and expanding rapidly today.

This result allows also an important decision support for the local officials of Casablanca, given that urban transport is structuring for all other urban activities. The indicator estimation allows to clearly highlight the non-accessible areas in the territory of Casablanca, such area is indeed clearly identified in the Maps obtained.

This research illustrates once again the key role of the use of GIS in urban planning and in urban transport in particular as strengthen in literature. The use of GIS has also enabled the integration of different urban data with a view to a more relevant analysis of the transport offer.

Moreover, it has been very clear through this example that the quality of the data is an essential factor for the accuracy and relevance of the result of the indicator estimation. The lack of urban data infrastructure forces us to strengthen and adapt the calculation methodology.

The proposed analysis of accessibility can of course, like previous studies presented in the literature section, be applied to urban services in particular such as health, shops, employment, this being, the SDG indicator aims for a global and general character over the whole area.

7. CONCLUSION AND PERSPECTIVES

Through this research, we were able to highlight the important role of transport and technological tools, in particular GIS, for urban planning through a literature review.

We have chosen to illustrate this idea in a context of sustainable development by calculating accessibility to the public transport networks of the city of Casablanca and its peripheral provinces: Mohammadia, Mediouna and Nouaceur.

The measurement of accessibility that we have carried out is based on a spatial approach as recommended by the SDG framework linked to the United Nations 2030 Agenda, in particular for our research the SDG indicator 11.2.1.

We were able to collect the necessary data in a GIS environment by proposing a Geodatabase grouping all the data. We then proposed a methodology adapted to the context of our study area and we were finally able to calculate the targeted indicator.

As for the methodology to estimate the accessibility indicator, it should finally be noted that we had to adapt it to the context of our study area, in particular due to the absence of a shared data infrastructure. In fact, the main changes introduced were the use of administrative boundaries as urban boundaries in view of the very high rate of urbanization of our study area, but also in view of the absence of a clear delimitation of this urban space. Existing modes of public transport also allowed us to limit ourselves to the analysis buffer zone of only 500 m. The context of spatial data in Casablanca led us to work a lot on the preprocessing, correction and updating of spatial data before arriving at the actual calculation. The use of sectors as the minimum breakdown of demographic data was chosen given the lack of very high-resolution demographic data.

Results obtained shows acceptable rates of accessibility in Casablanca center city. Also, there is an improvement in this population accessibility after the introduction of tram lines. However, the accessibility in peripheral area as estimated, shows less rates of accessibility, for these recently urbanized areas.

Indeed, the results confirm on the one hand the greater public transport offer in the center of Casablanca compared to its peripheral areas and on the other hand the importance of the introduction of the tram network to improve the value of accessibility to the citizens of the center city.

We could then conclude that the calculations obtained show the inequity of the public transport offer between the populations living in Casablanca center and those living in its periphery. This can lead to an imbalance in terms of activities and access to opportunities between all the whole populations of the Casablanca region. This lack therefore prevents the fulfillment of the role of urban public transport to support, and above all to structure, the urban extension experienced by these peripheral areas.

We note that there are still open issues that need to be resolved once needed data is available. The accuracy of the calculation could be improved by using disaggregated data from the general population census. It should also be noted that taking into account the geolocation of urban activities and residential areas rather than the hypothesis of a homogeneous distribution of the population can certainly improve the calculation model.

It is also interesting in future work to test and compare the results taking into account a broader definition of accessibility to public transport, taking into account other parameters such as cost, quality of service and traffic density. That said, this of course remains outside the scope defined by the SDG indicator 11.2.1.

This research thus contributes to the efforts to implement the objectives of the 2030 Agenda, particularly concerning urban transport. The example of the city of Casablanca could easily be transposed to other Moroccan cities. Moreover, and as a research perspective, our SGEO research team is working on the calculation of other SDG indicators, particularly those for which GIS represents an essential tool for their calculation.

Finally, we highlight the efficiency and reusability of the used methodology in order to monitor the indicator of accessibility to urban transport over time, especially to assess the contribution of future tram projects T3 and T4 and future BRT lines BW1 and BW2 mentioned above and currently under construction in Casablanca.

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