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Article

Analysis of access to amenities in peri-urban areas in West Africa: A GIS-based approach in Abomey-Calavi, Republic of Benin

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Abstract: Urban facilities and services are essential to human life. Access to them varies according to the geographical location of the population, whether urban, peri-urban or rural, and according to the modes of transport available. In view of the rapid development of peri-urban areas in developing countries, questions are being asked about the ability of the inhabitants of these areas to access these facilities and services. This study examines the ability of the inhabitants of Hêvié, Ouèdo and Togba, three peri-urban districts of Abomey-Calavi in the Republic of Benin, to access commercial, educational, school and health facilities. To this end, we have adopted a GIS-based methodology. It is a combination of isochronal method and accessibility utility measurement. The isochrones were produced according to the main modes of travel recorded on the study area and over a time $t \leq 20$ min divided into intervals of 05 min. Analysis of the data enabled us to understand that the main modes of travel adopted by residents are walking, motorcycle and car. Access to educational and health facilities is conditioned by the mode of travel used. Access to commercial and entertainment facilities in $t \leq 20$ min is not correlated with the modes of transport used.

Keywords: GIS; isochronous; accessibility; amenities; periurban

1. Introduction

Urban areas bring together people, activities (economic, Entertainment and sport, educational), services and housing, all of which work to the benefit of each other. Cities enable residents to live close to their economic activities, and to create and meet their needs in terms of infrastructure, services and housing.

Against a backdrop of rapid urban growth worldwide, cities are called upon to raise the level of services, infrastructure and housing in order to increase their efficiency (Alavi et al., 2024; Hassanzadehkermanshahi and Shirowzhan, 2022; Kayizzi-Mugerwa et al., 2016; United Nations Department of Economic and Social Affairs, 2019). Limited financial resources and strong demographic growth in the Global South do not allow that municipalities to bridge the equipment gap across the entire territory undergoing urbanization (Nicolas, 2017; Rapport 2021 sur les pays les moins avancés, 2021). Do today's suburban areas provide residents with access to the amenities essential to their daily lives? Are these facilities accessible using the various modes of transport available to the population? Or are suburban areas reinforcing social inequalities within our societies?

In some countries, such as the Republic of Benin, where there is great interest in living in (or near) the economic capital city, the latter is subject to rapid territorial expansion. Indeed, Abomey-Calavi, a municipality located to the west of Cotonou (the economic capital), is experiencing this growth. The municipality of Abomey-Calavi recorded a national growth rate of 6.93% between 2002 and 2013, and accounted for 46.9% of the Atlantic department's population (Osseni et al., 2023), one of Benin Republic's twelve departments. Today, this phenomenon can be seen in districts that are increasingly distant from Cotonou, with densities ranging from 600 to 850 inhabitants per km^2 (Hounsounou, 2019). The low density of this sparsely-populated residential fabric calls for careful consideration and study of the consequences of this urban sprawl, in order to protect the environment and the population from uncontrolled urban sprawl and inaccessibility to social amenities and services. Uncontrolled urban expansion in the case of Cotonou and Abomey-Calavi, which is leading to a number of problems, including the reduction of agricultural and natural areas, growing greenhouse gas emissions, difficulties of access to basic social and community facilities, and land tenure problems (Hounsounou, 2019). It also leads to increased investment needs on the part of the local authority to extend social services. According to Rubiera-Morollón and Garrido-Yserte (2020), it is generally thought that sprawl leads to the predation of land, which has an inverse effect on cities and the natural environment. It also lengthens distances within cities, making movement more complex (Rubiera-Morollón and Garrido-Yserte, 2020). This work examines the ability of residents in suburban areas to access facilities.

Accessibility is the key concept in both urban planning and transport (Geurs and Östh, 2016; Martínez et al., 2021) and various pioneering theories of urban planning are based on accessibility (Bentlage et al., 2013; Bhellar et al., 2023). For this reason, the question of accessibility in urban space is widely studied in the literature. Different definitions are used in the literature. Accessibility is seen as the ease of physical access to activities, facilities and places (Geurs and Östh, 2016; Saif et al., 2019; Vitman-Schorr et al., 2019). Accessibility is also the ability to receive products, services and activities and to reach desired locations—also known as opportunities (Litman, 2003; Vitman-Schorr et al., 2019); it is the set of possibilities for accessing geographically distributed opportunities (for work, Entertainment and Sport, interaction) (Hansen, 1959; Páez et al., 2012). It can also be described as the ease with which an individual can perform an activity that she chooses (Scheepers et al., 2016). According to Geurs and van Wee (2004), accessibility is "...the extent to which land-use planning and transport systems enable (groups of) individuals to reach activities or destinations using (a combination of) transport mode(s)" (Geurs and Östh, 2016). Thus, accessibility is defined as the ease with which a space (or an activity) can be reached by eliminating all constraints and ensuring distribution in the space concerned (Geurs and van Wee, 2004; Hansen, 1959; Ingram, 1971; Marwal and Silva, 2022). According to Marwal and Silva (2022), accessibility is assessed through three components: land use, transport and the individual. In this article, we will be focusing on land use and transport (more specifically, access to facilities, transport modess and existing roads). As accessibility plays an essential role in reducing social exclusion and improving public health and the well-being of city dwellers, it has long been considered a key criterion or indicator for the evaluation of urban and transport policy (Curl et al., 2011; Jamei et al., 2022; Shen et al., 2020). It is also possible to evaluate proximity or accessibility in terms of time (Iamtrakul et al., 2024). Cities must therefore enable different residents to access facilities in a relatively short time and under good conditions. The 20-min city is a politically popular concept today, due to the perceived equal treatment of populations it provides. The 20-Minute City (better known as the 15-Minute City or the Quarter-Hour City) is a city that promotes densification of urban space, sustainability of the urban environment, and sustainable development (Monteiro et al., 2023). The concept bears similarities to several well-known urban planning ideas, like Ebenezer Howard's Garden City, Jacob's Mixed Land Use, Perry's notion of community cohesiveness, pedestrian districts, and the "New Urbanism"-developed urban livability (Dunning and Nurse, 2021; Dunning et al., 2023; Gower and Grodach, 2022). The concept advocates access to various needs and activities on foot or by bicycle in 15 min (Dunning et al., 2023). Access time to a facility therefore varies between 15 and 20 min at most. The 15-minute method, often referred to in the literature as the 15- or 20-minute city or neighborhood, seems to be a fairly popular model for the functional and spatial organization of both the neighborhood and the city as a whole (Dunning et al., 2023; Pozoukidou and Chatziyiannaki, 2021). The idea of the neighborhood has gradually evolved in the process of designing the perfect city, from the physical footprint of well-organized urban services to a medium for social data and ideals (Dunning et al., 2023; Καυκαλάς et al., 2016). In West Africa, peri-urban areas are characterized by poor access to basic services and facilities (Ebnou Abdem et al., 2023; Ekpodessi and Nakamura, 2023; Weiss et al., 2018), especially in a geographical context marked by limited access to public transports, motorized vehicles and by various financial constraints (Lartey and Glaser, 2024; Mittal et al., 2023; Schoch and Lakner, 2020). According to Iamtrakul et al. (2024), the local context of the study area is of vital importance in assessing accessibility. Mitropoulos et al. (2023) researches show that there exist disparities in accessibility between different modes of transport and a range of options (such as places and activities for recreation, educational institutions, and medical facilities).

The importance of each research area's local environment has been underlined by a number of earlier studies (Mitropoulos et al., 2023), which took into account the various locations of services and activities as well as the range of accessible travel alternatives. In a global context where it is increasingly important to bring facilities closer to the population for more sustainable cities, the issue of access to facilities in polluting less received very little attention in West African cities, especially in the specific case of Benin's peri-urban areas. In the light of these works previously mentioned, we note that very few studies on physical accessibility in peri urban area have been carried out in West Africa. The aim of the present study is to reduce this gap and assess accessibility in peri-urban areas using a GIS-based approach in taking account the different modes of transport.

2. Materials and methods

2.1. Study area

The main urban continuum in the Republic of Benin is the Grand Nokoué, which groups together five (05) municipality in the south of the country: Cotonou, Ouidah, Sèmè-Podji, Porto-Novo and Abomey-Calavi. This urban area has undergone rapid territorial and population growth in recent decades. With a population of 1,388,190 in 2002, it rose to 1,984,425 in 2013 (DIRECTION DES ETUDES DEMOGRAPHIQUES (INSAE), 2015) for a national population of 10,008,749 in 2013; i.e., around 20% (19.83%) of the national population on 1.27% (1453 km^2) of the country's total surface area.

The site concerned by our study is part of the peripheral extension zone of Abomey-Calavi, one of the fast-growing municipalities of Grand-Nokoué. The municipality of Abomey-Calavi is located to the west of Cotonou (the economic capital of the Republic of Benin), and this position is conducive to population growth. This rate was estimated at 6.93% between 2002 and 2013. The study area comprises three (03) districts (Hêvié, Ouèdo and Togba) of the nine (09) that make up the municipality. Its population increased from 168,071 in 2013 to 327,544 in 2022. **Figure 1** below shows the location of the study area.

Housed in the continuity of the cities of Cotonou and Abomey-Calavi, the districts of Hêvié, Ouèdo and Togba meet all the characteristics of a suburban territory. They are between urban and rural area, there is a simultaneous presence of agricultural areas, residential areas, facilities. The site is also subject to a rapidly changing low occupancy density. Indeed, with an occupancy density of 1385.27 population/km^2 in 2013 to 2699.67 population/km^2 in 2022. This is an occupancy density that has practically doubled in nine (09) years.

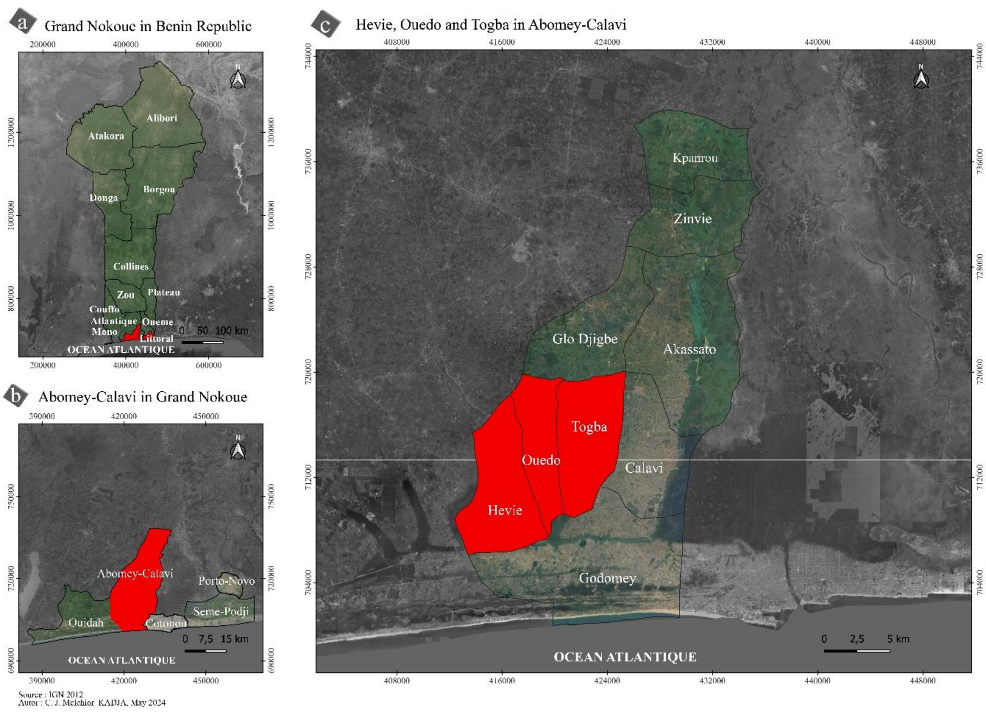


Figure 1. Study area: Hêvié, Ouèdo, Togba. **(a)** Grand Nokoué in Benin Republic; **(b)** Abomey-Calavi in Grand-Nokoué; **(c)** study area in Abomey-Calavi.

2.2. Measuring and applying accessibility

Six (06) different methods are used to measure the accessibility of a territory. These are 1) the Ischronian Method based on the number of destinations in a set of travel times or distances defined from a residence, 2) the Gravitational Method of accessibility based on the gravitational interaction between dwellings and infrastructures, 3) the Accessibility Utility Measure, which defines destinations of maximum utility, taking mobility behavior into account, 4) the Constraint Measure, which studies the tasks to be performed and the resources that can be devoted to these tasks, 5) the Data-Based Accessibility Measure, 6) Accessibility analysis using proximity indices, which defines the accessibility index for a specific space (often a rectangle, square or hexagon).

Table 1 below lists the different methods encountered in the literature.

Table 1. Accessibility measurement methods.

Nº	Method	Advantages	Disadvantages	Authors
1	Isochronian: Based on the number of destinations in a set of travel times or distances defined from a residence.	Simple	Excludes installations beyond a certain distance	(Neuburger, 1971; Vickerman, 1974; Wubneh and Shen, 2004)
2	Gravitational accessibility method: This approach is based on the gravitational interaction between housing and infrastructure.	Conceptually easy	Depends largely on impedance factor and system weightings	(Hansen, 1959)
3	Accessibility utility measurement: takes into account mobility behavior, and defines destinations of maximum utility.	Takes residents' preferences into account		(Ben-Akiva and Lerman, 1985; Chorus and De Jong, 2011; Dong et al., 2006)
4	Constraint measurement: It studies the tasks to be performed and the resources (i.e. time) that can be devoted to these tasks.	Overlapping method combination	Superimposed constraints	(Miller, 2005; Wu and Miller, 2001)
5	Data-driven accessibility measurement: using location data in a variety of ways.	Diversified use	Need to access data such as digital points of interest, cell phone or GPS data, or physical data at plot construction level	(Li et al., 2011; Omer, 2006; Shen, 2005; Santos et al., 2019;)
6	Accessibility by Proximity Index (API)	Defining the index of accessibility in a specific area (Hexagone or square)	Necessitate the direct mapping of network indicators onto an accurate digital simulation base structured on a map topology (road graph) comprising lines (roads) and points (intersections).	(Iamtrakul et al., 2024)

Accessibility has been the subject of a variety of planning and policy studies. Notably on various types of urban services and/or facilities (Gonzalez-Feliu et al., 2014; Hewko et al., 2002; Viana Cerqueira, 2020), transport and transit facilities (Paul, 2012), health facilities (Bell et al., 2013; Bissonnette et al., 2012; Luo and Wang, 2003), green spaces for rest and play (Boone et al., 2009; Iraegui et al., 2020; Rigolon, 2016), educational facilities (Mei et al., 2019). This study will focus on most used facilities by the residents.

2.3. Measuring accessibility in this study

In this research, we evaluate residents' accessibility in relation to specific travel times, based on their preferred locations and their transports modes. To do this, we combine two of the methods listed in **Table 1**. These are Isochronian Measurement and Accessibility Utility Measurement. This approach allows us to draw conclusions about which facilities are the most widespread and which are the most accessible. Also, by comparing the different modes of transport most used by the population and highlighting the relationship with accessibility, we can understand the reasons behind the choice of transport modes.

Following this choice of methods, we carried out the accessibility assessment in three (3) stages: 1) Identification of the most visited facilities, 2) Modes of transport and travel speed, 3) Facilities accessibility maps and statistical analysis of the relationship between infrastructure access and modes of transport used.

(1) Identification of preferred locations (location of most visited facilities):

Preferred locations and travel modes vary from one individual to another. In order to define the preferred locations and travel modes of different households, we introduced survey questionnaires to a representative sample of the population.

The unit of measurement considered in the population is the household. These households are represented by the head of household, and are selected on the basis of simple random sampling applied to the entire study area. Based on Daniel Schwartz's formula (Allarané et al., 2024), we calculated the sample size in relation to the total population of the study area.

$$N = \frac{z^2 \times p(1-p)}{d^2} \tag{1}$$

where N is the sample size; z = 1.96 is the 95% confidence level according to the centered normal distribution; p = proportion of the population selected; d = 5% is the tolerated margin of error.

Table 2. Sampling of the survey population.

District	Number of respondents	Percentage (%)
Hêvié	154	39.99
Ouèdo	63	16.38
Togba	168	43.63
Total	385	100

The surveys enabled us to define the facilities according to the main facilities used by the population (education, health, Entertainment and Sport). To locate these facilities, we use OpenStreetMaps (OSM), which are then supplemented by data from the Abomey-Calavi municipality and our field surveys (Iamtrakul et al., 2024).

(2) Modes of transport and travel speed:

Using the previous survey population (**Table 2**), the most used modes of transport in the study area were defined. Travel speeds are evaluated according to the 03 main travel modes used on the study area.

Walking Speed:

To define the speed of pedestrians, we chose a method of observation and direct measurement of speed. In fact, we measured pedestrians' travel time by timing the movement of passers-by over a distance of 10 m. In fact, we preferred to use the "10-meter walk test" to assess pedestrian speed on our study area. Very often used in clinical research, this method proved to be appropriate to the realities of our study because it is easy, reliable, fast and inexpensive (Gafner and Bruyneel, 2022; Graham et al., 2008). This speed measurement was carried out according to the types of lanes recorded on the study area.

Speed of motorized vehicles (cars and motorcycles):

To obtain information on motorized vehicle speeds, we used Google Maps data (Meire and Derudder, 2020; Muñoz-Villamizar et al., 2021). The information collected concerned the travel times of the sections according to the two motorized modes recorded (motorcycles and cars). Based on these travel times, we calculated the speed on the network using the formula:

$$v = \frac{d}{t} \quad (2)$$

with v corresponding to speed, d to distance and t to time.

By applying this formula to each of the lanes defined in our sample, we obtain the speeds for the different lanes in the network and according to the different modes of transport.

Sampling:

Average speed on a lane is influenced by factors such as topography, surfacing, modes of transport, function and lane rights-of-way. The topography of the study area does not show any significant variation. It therefore has very little influence on the speed recorded on the study area's roads. The function (type-primary, secondary, tertiary, service) of the road is an important criterion taken into account in our analysis. As far as pavement is concerned, there are three main types of coated (bare ground, pavement and asphalt) on the study area. Coating is therefore a key parameter in our study. In Hêvié, Ouèdo and Togba, the road right-of-way is one of the basic elements used to classify roads according to their function. It is therefore irrelevant to consider the road right-of-way as an analysis criterion once the function of the road is considered as an analysis criterion.

The selection of the sample was therefore based on two criteria: surfacing and function. In order to define speeds according to these criteria, a diversified sample of sections was selected on the basis of different surfacing and functions. A total of twenty (27) different sections were selected throughout the study area, ten (10) of which were asphalt roads and seventeen (17) earth roads.

(3) Facilities accessibility maps based on isochrones and statistical analysis of the relationship between infrastructure access and modes of transport used:

Network modelling is a step that enables us to obtain (as a shapefile) the road structure of the study area, on which the mapping work will be based. In the absence of an official database, we turned to the Open Street Maps (OSM) open-access database. We then extracted the study area's road network from this open-access database, and completed it with data from the Abomey-Calavi town hall (the administration in charge of urban roads in the study area). These files provided us with the lane lengths, functions and coating. The speeds evaluated in the previous step were used to update the characteristics of the various lanes. After updating the road-related characteristics for each type of equipment concerned by the study, the layer is created (using "PostGis").

Once the layers have been created, the isochrones are created.

According to Viana Cerqueira (2020), accessibility to facilities is assessed on the basis of the ability of residents to reach them in a maximum of 20 min. For the purposes of this study, access to a facility is assessed on the basis of 20 min, according to the main modes of transport used on the study area. As part of this study, using GIS (Geographic Information Systems), we define on a map the access time to facilities (destinations) as a function of the average speeds recorded in relation to the different modes of transport (walking, motorized two-wheelers, private cars) recorded on the territory.

The isochrone maps in this study are designed according to four-time intervals for each mode of transport and each type of equipment selected. The time intervals considered are regular, with a 05 min jump each time. Thus, the time intervals considered in our work are: [0–5 min]; [0–10 min]; [0–15 min] and [0–20 min].

Given the specificities of our study area, where 1) motorcycles are the mode of transport preferred by the population, and 2) where travel speeds incorporate realities such as the absence of road surfaces and maintenance, the use of these extensions would be counterproductive. We therefore use the ArcMap extensions of ArcGis 10.8 to create the isochrones, as they enable us to assign speeds according to the particularities of the roadway and to consider modes of transport not taken into account by the above-mentioned extensions.

All households living within an isochrone are considered to have access to the facilities according to the mode of transport considered and in relation to the type of facility assessed. For example, if 10% of all households are housed in the territory defined by the isochrone for the 05 min walk to educational facilities, then educational facilities are accessible to 10% of households in five minutes.

Following the production of the isochrone maps, which enabled us to define the accessibility of households to the various infrastructures according to the modes of transport used, it was important to see the relationship between accessibility and the various modes of transport. To do this, we performed the Chi^2 statistical test using "R-Studio" software. This test is used to assess the dependency between modes of transport and access to infrastructure. The test is performed for values derived from isochrones for times $t \leq 20$ min. The dependence between a modes of transport and access to a facility is confirmed for a p-value below the 5% threshold ($p < 0.05$).

Figure 2 shows how isochrones are obtained in this study.

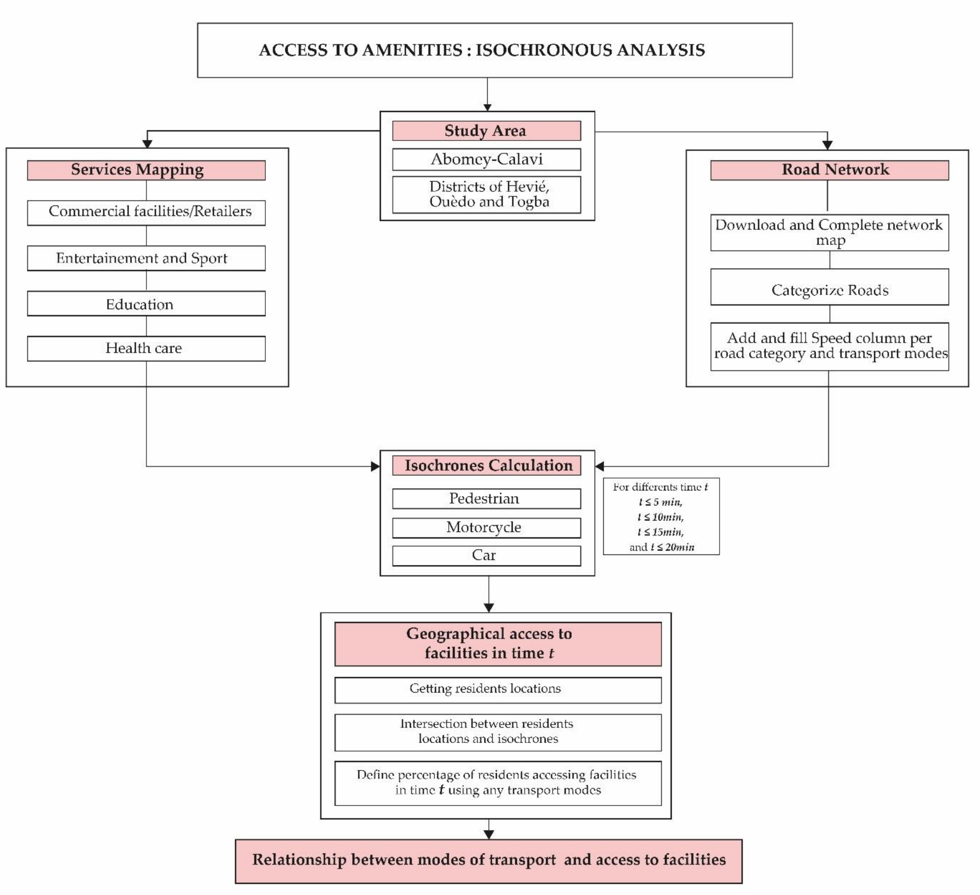


Figure 2. Process for accessibility analysis.

3. Results

The methodology we have developed has enabled us to obtain results on the most frequented facilities, the main modes of transport, on the access to these facilities and the relationship between this accessibility and the modes of transport used. Our results are presented in three main sessions. The first section identifies the most frequently used facilities. The second section shows preferred modes of transport and the speeds of the various modes of transport and routes recorded on the study area. The third section determines the accessibility maps and the relationship between accessibility and transport modes used.

3.1. Identifying most visited facilities

Household data collection enabled us to identify the types of facilities most visited in our study area. The facilities most visited by households in Hêvié, Ouèdo and Togba are, respectively, shopping facilities, entertainment and sport facilities, educational facilities and health facilities. The cumulative responses from the various households show that 62.86% of households rank commercial facilities among the four main facilities most frequented by the household. As shown in **Table 3** below, this figure is 20.26% for entertainment and sport facilities, 14.55% for educational facilities and 14.03% for health facilities.

The main factor in the choice of facilities to be evaluated is the importance attached to them by residents. This study considers both private and public facilities.

The absence of transportation facilities in this list is justified by the absence of a formal transportation system on the study area. This implies the absence of a railway station, metro station, bus stop or multimodal hub.

As for the modes of transport most used by residents, the most common are motorized two-wheelers, cars and walking. These modes of transport represent the main travel mode for 57.40%, 31.69% and 10.65% of households respectively.

Table 3. Results on most visited facilities by the population.

	Services	Rank	Percentage	Number of respondents
	Types of facilities			
Commercial facilities/Retailers	Restaurants, convenience store, Markets.	1	62.86%	242
Entertainment and Sport	Public parks, sport fields, bars, playgrounds.	2	20.26%	78
Educational	Educations, Libraries.	3	14.55%	56
Health	Clinics, hospitals and pharmacies.	4	14.03%	54
Worship	Temples, Churchs, mosque.	5	9.87%	38
Total			100%	

Figure 3 below shows the location of each of the four main categories of facilities most frequently visited.

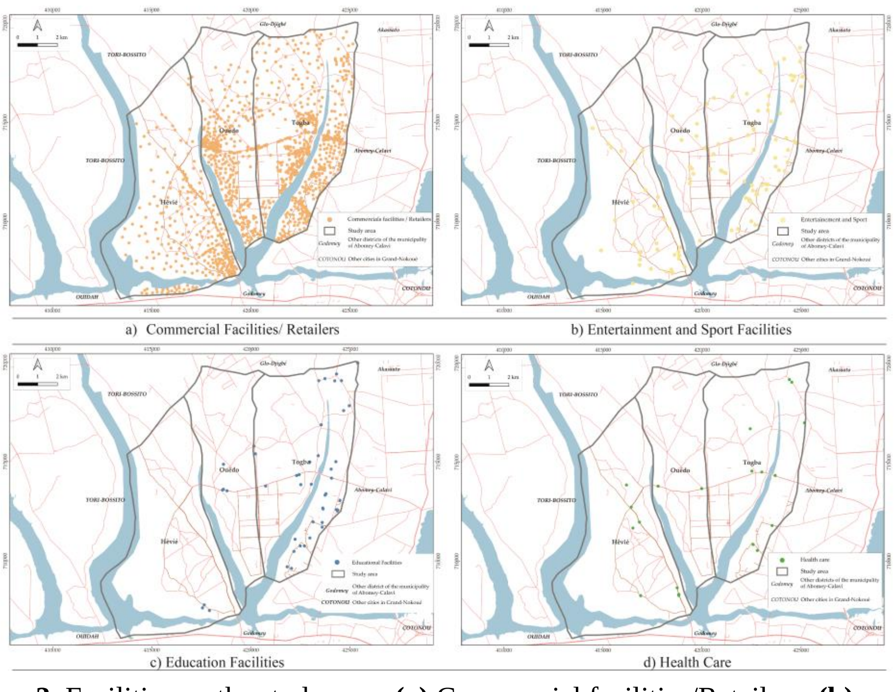


Figure 3. Facilities on the study area. **(a)** Commercial facilities/Retailers; **(b)** Entertainment and Sport Facilities; **(c)** Education Facilities; **(d)** Health Care facilities.

3.2. Modes of transport and travel speeds

(1) Modes of transport:

The field surveys also enabled us to define the modes of transport preferred by the population for their daily journeys. In general, the preferred mode of transport is the motorcycle (57.40%), followed by the car (31.69%) and walking (10.65%). Minibuses are used very rarely by the residents of in Hêvié, Ouèdo and Togba accounting for only 0.26%. It should be emphasized that, for the purposes of this study, the categorization of modes of transport do not distinguish between private and public transport. **Figure 4** below shows the preferred means of transport for the resident population

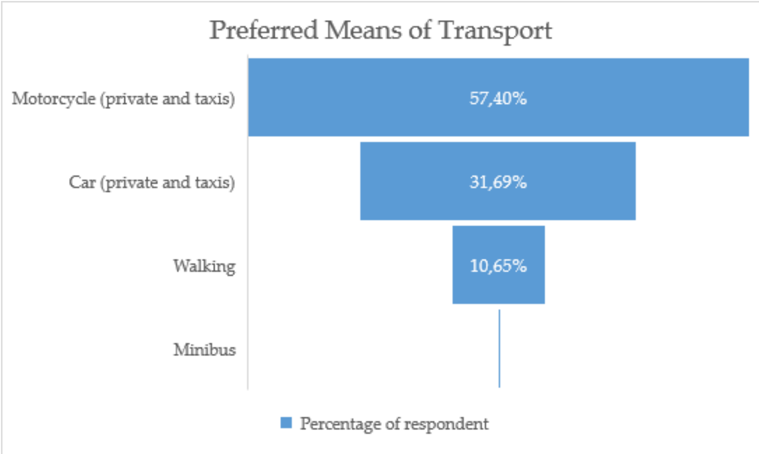


Figure 4. Preferred modes of transport.

(2) Walking Speed:

The speed of pedestrians was assessed throughout the Hêvié, Ouèdo and Togba areas as part of this study. Pedestrians have an average speed of 1.47 m/s on asphalt (and paved) roads and 1.39 m/s on bare ground. The average speed on all lanes is 1.43 m/s or 5.14 km/h, as shown by **Figure 5**.

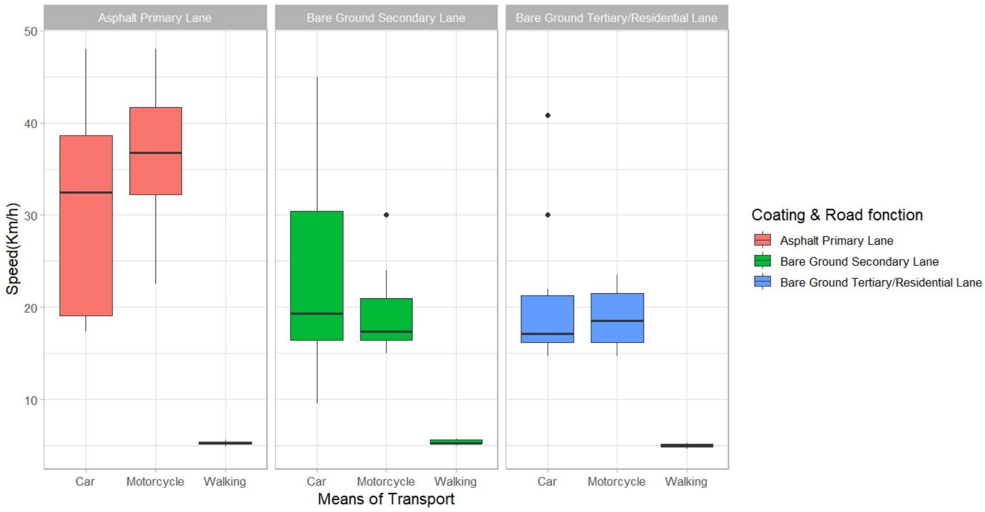


Figure 5. Travel speed by modes of transport and coating and road function.

(3) Motorized transport speeds:

The various modes of motorized transport available in the Hêvié, Ouèdo and Togba districts enable the population to travel at varying speeds. The average speeds recorded in relation to these different modes and in relation to the different roads encountered in the study area were evaluated during this study.

The graph shows that speeds recorded on asphalt and paved roads are higher for motorized modes of transport than for unmade roads as a whole. A maximum of 48 km/h and a minimum of 15 km/h are recorded for motorized modes. More specifically for cars, we note an average speed of 32.43 km/h on paved roads, while the median speed is between 20 and 15 km/h for unmade roads (secondary and tertiary). As far as motorized two-wheelers are concerned, the average speed for the primary lane is much higher than those recorded for the other lanes; i.e., an average speed of 36.88 km/h for the asphalt lane compared with average speeds of 19.62 km/h and 18.73 km/h respectively for the bare secondary lanes and bare tertiary lanes. The difference between speeds and road surfaces is less noticeable when walking.

Generally, speeds vary according to the mode of transport adopted by residents. Motorized modes of transport achieve speeds well above those recorded by pedestrians, which vary between 4 and 6km/h on all lanes. Speeds between cars and motorized two-wheelers are relatively approximate, with variations always below 10 km/h.

3.3. Access to amenities

(1) Household access to amenities

Table 4 shows an overview of household access to the facilities in defined time intervals ($t \leq 5$ min; $t \leq 10$ min; $t \leq 15$ min; $t \leq 20$ min).

Table 4. Isochrones/Access to facilities.

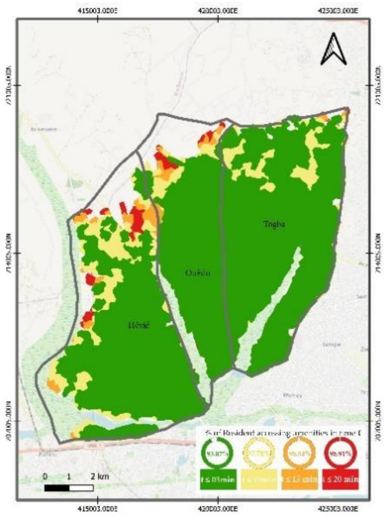
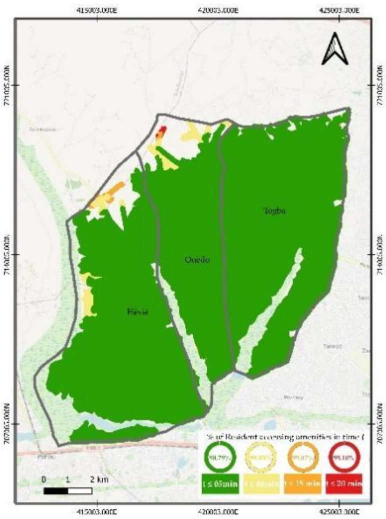
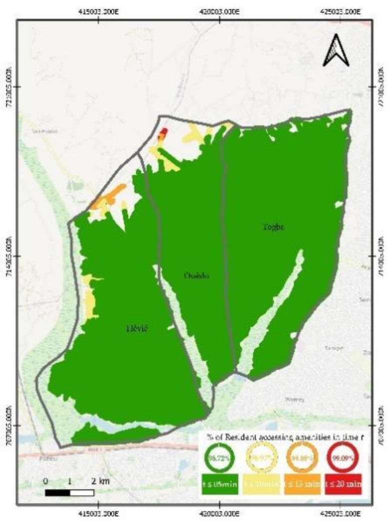
Walking	**Motorcycle**	**Car**
Commercial facilities and Retailers		
		
a) Access for pedestrian to commercial facilities	b) Access for motorized two wheelers to commercial facilities	c) Access for cars to commercial facilities

Table 4. (*Continued*).

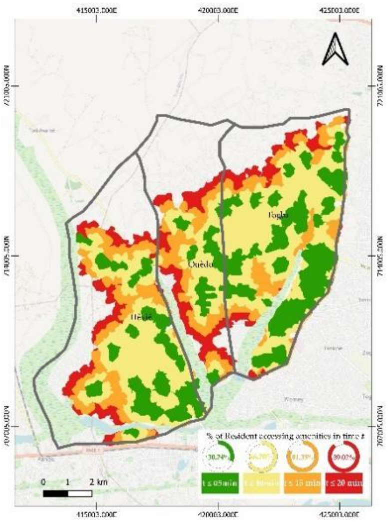
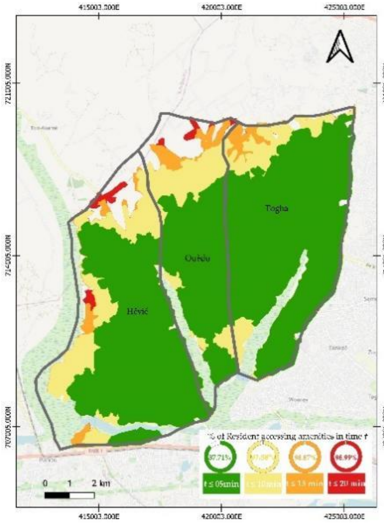
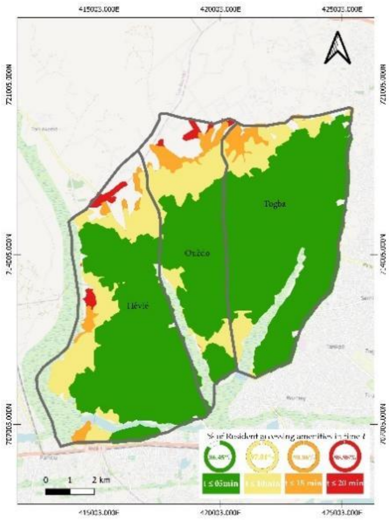
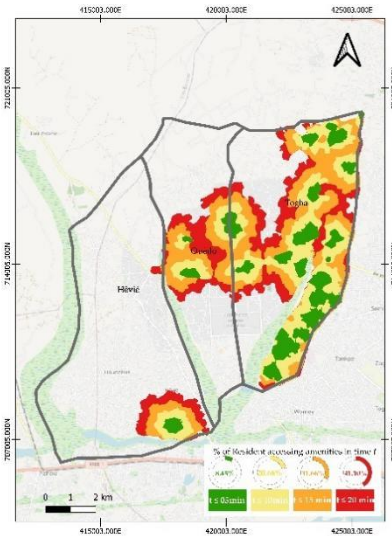
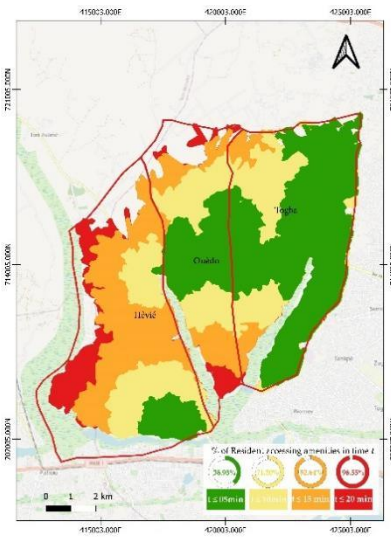
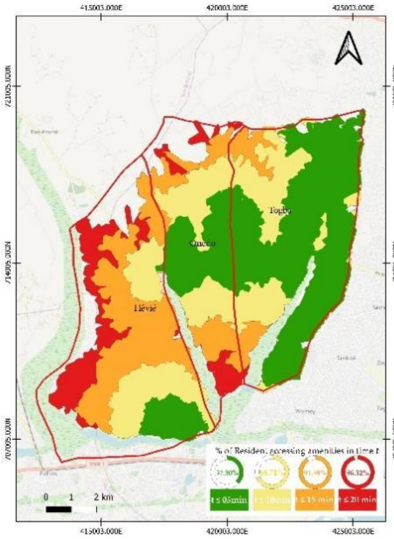
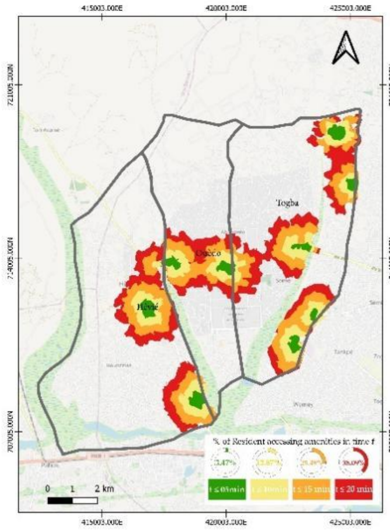
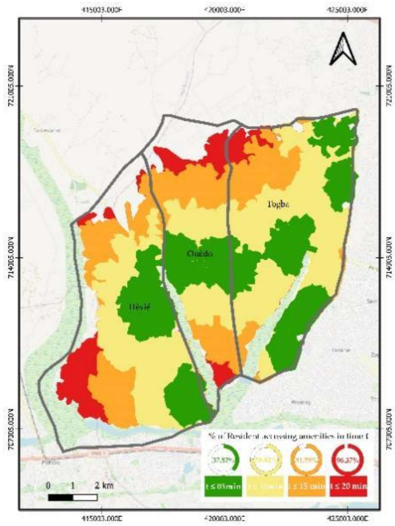
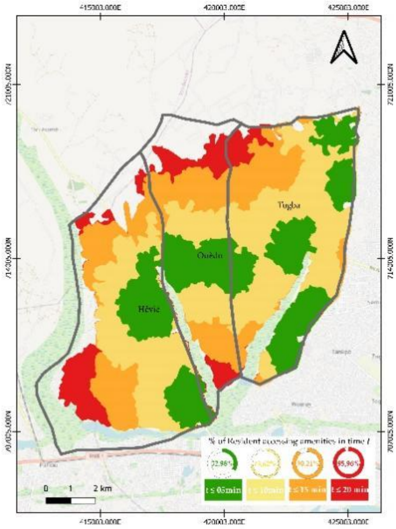
Walking	Motorcycle	Car
Entertainment and Sport Facilities		
		
d) Access for pedestrian to entertainment and sport facilities	e) Access for motorized two wheelers to entertainment and sport facilities	f) Access for cars to entertainment and sport facilities
Education		
		
g) Access for pedestrian to education facilities	h) Access for motorized two wheelers to education facilities	i) Access for cars to education facilities

Table 4. (*Continued*).

Walking	**Motorcycle**	**Car**
Health Care		
		
j) Access for pedestrian to health care	k) Access for motorized two wheelers to health care	l) Access for cars to health care

The maps inserted in **Table 4** show the areas covered by the facilities according to the different modes of transport in $t \leq 5$ min (green); $t \leq 10$ min (yellow); $t \leq 15$ min (orange) and $t \leq 20$ min (red).

Table 5. Results for households able to access facilities in less than 20 minutes by different modes of transport and Chi2 statistical test.

HOUSEHOLD ACCESS TO AMENITIES					**Dependance**
	Time interval t (minutes)				
	$t \leq 5$ min	$t \leq 10$ min	$t \leq 15$ min	$t \leq 20$ min	
Modes of transport	Percentage (%) of households served				p-Values
Commercial Facilities/Retailers					$p = 0.9999$
Walking	93.07%	97.78%	98.54%	98.905%	
Motorcycle	98.79%	99.03%	99.07%	99.10%	
Car	98.72%	98.97%	99.076%	99.09%	
Entertainment and Sport Facilities					$p = 0.7075$
Walking	30.24%	66.70%	81.39%	89.02%	
Motorcycle	87.71%	97.38%	98.87%	98.99%	
Car	86.45%	97.01%	98.86%	98.98%	
Educational Facilities					$p = 2.072 \times 10^{-6}$
Walking	8.45%	20.66%	31.66%	41.10%	
Motorcycle	38.98%	71.20%	92.64%	96.55%	
Car	37.30%	68.71%	91.58%	96.32%	
Health Facilities					$p = 4.394 \times 10^{-7}$
Walking	3.47%	12.87%	25.49%	38.09%	
Motorcycle	37.82%	75.82%	91.29%	96.37%	
Car	32.98%	73.62%	90.21%	95.96%	

Tables 4 and **5** and **Figure 6** show that households living in Hêvié, Ouèdo and Togba have limited access to facilities when they use walking as a mode of transport. Only 41.10% of households have access to an educational facility in less than 20 min on foot. This figure is 30.47% for Entertainment and Sport facilities and 38.09% for health facilities.

Unlike walking, motorcycles provide access to a greater number of households. Indeed, for the same time period ($t \leq 20$ min) considered above, motorized two-wheelers enable 96.55% of households to access educational facilities, 96.37% to access health facilities and 98.99% to access Entertainment and Sport facilities.

From this, we can deduce that access to amenities in the suburbs is conditioned by the modes of transport used. This explains the high propensity of residents to use motorized modes of transport.

(2) Relationship between facilities accessibility and modes of transport:

Figure 6 below illustrates the population's geographical accessibility to social amenities by modes of transport for a time of less than 20 minutes. Analysis of this figure shows that shopping and Entertainment and Sport facilities are more accessible to the population, whatever the modes of transport used. The Chi² statistical test applied to the proportions of Entertainment and Sport and commercial facilities shows p-values of 0.70 and 0.99 respectively. As these values are above the 5% threshold, they indicate that the difference between the proportions according to the type of modes of transport is not significant. This suggests that access to these two types of modes of transport is not significant. This suggests that access to these two types of equipment in less than 20 min ($t \leq 20$ min) does not depend on the travel modes.

In contrast, health and education facilities show lower proportions for the pedestrian category. Chi² tests show p-values below the 5% threshold (4.394e-07 and 2.072e-06 respectively). These p-values indicate a significant difference between the proportions for pedestrians, motorcycles and cars. This implies that access to health and educational facilities is highly dependent on the type of transport used.

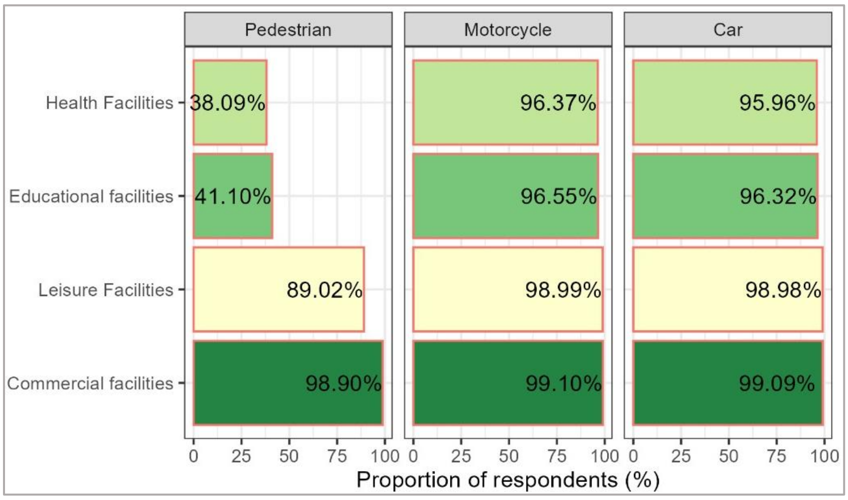


Figure 6. Geographical accessibility of the population to social facilities by type of transport for $t \leqslant 20$ min.

4. Discussions

4.1. Facilities and services

The amenities required for everyday life are diverse, and differ depending on the city studied. The literature shows a multitude of amenities to which city dwellers are accustomed and which affect their choice of residence (Huang and Du, 2015). In city centers and older neighborhoods, these include public transport facilities, schools (for families with children of school age), public institutions and open spaces for outdoor activities (Zhang and Yan, 2023).

For peri-urban areas such as Hêvié, Ouèdo and Togba, the most visited service locations are less studied in the literature. Our results address this issue. They show that the most visited facilities in peri-urban areas are sometimes different from those found in city centers. In Hêvié, Ouèdo and Togba, there is little interest in public transport facilities, given the absence of a public transport system. Local shops are very popular, as they have been developed to meet the growing need for food supplies. In the absence of landscaped green spaces accessible to all, various leisure and sports facilities are frequently used by the population for outdoor activities. For a population that is predominantly young and of school age, educational facilities are also very popular. There is also a growing interest in health facilities and places of worship in West African peri-urban areas.

4.2. Preferred modes of transport and travel speed

The three mains modes of transport recorded in the peri-urban area studied are motorized two-wheelers, cars and walking. Previous studies show that in emerging cities (such as Addis Ababa, Lima and Delhi) and "suffering" cities (such as Nairobi and Dar es Salaam), the main modes of transport are walking, bicycles, informal public transport, cars and motorized two-wheelers (Venter et al., 2019). In the Republic of Benin, the vehicles most frequently registered by the Agence Nationale des Transports Terrestres (ANAT) are motorized two-wheelers, tricycles and private cars (SSATP and Ministère des Infrastructures et des Transports, 2019). Our study concurs with the findings of various authors, but makes a distinction with regard to other emerging or "suffering" cities, as well as other cities and territories in Benin. The lack of interest in bicycles in peri-urban areas can be explained by the absence of road improvements to make this mode safe, and by the ease of access to motorcycles, which can cover longer distances in much less time.

The speed in an area is linked to the surface and condition of the roads recorded (Sun et al., 2023). Whereas in city centers, speeds are reduced by frequent stops due to congestion, traffic lights and crosswalks (Boggio-Marzet et al., 2021), in the peri-urban areas covered by our study, speeds are reduced by the poor quality of the pavement and roads coating. Our study confirms the relationship highlighted by previous studies between speed and road surface. Our study also shows that speed varies from one mode of transport to another.

4.3. Access to amenities

The isochrones obtained for the different facilities and modes of transport show unequal access to facilities in the peri-urban area studied. These results confirm the work of Ekpodessi et al (2023), Ebnou et al. (2023) and Weiss et al. (2018). Spatial inequalities in the suburbs are linked to constraints such as the lack of a private car (or other motorized transport), financial difficulties in affording one, and the absence of official, high-performance public transport services (Hewko et al., 2002; Lartey and Glaser, 2024; Mittal et al., 2023; Rougé, 2005; Schoch and Lakner, 2020). The results of our study show that access to school and healthcare facilities in a time $t \leq 20$ min depends on the mode of transport used, {Citation}. On the other hand, leisure and shopping facilities are not dependent on the mode of transport used. This difference can be explained by the proliferation of shops in urban and peri-urban areas, as shown by the work of Zhang et al. (2023) and Yang et al. (2020) who highlight the high level of accessibility to shops.

Aware of the link between mode of transport and access to certain facilities, households mainly use motorcycles for their journeys, a situation favoured by the characteristics of motorcycles, which provide rapid, low-cost access to the various peri-urban and rural areas, thus enabling wider access to the various amenities necessary for daily household life (Chenal, 2017; Ngo, 2015). Against a backdrop of uneven distribution of amenities and their inaccessibility to the majority on foot, households are continually turning to lower-cost, motorized modes of transport to get around the suburbs.

To reduce the social inequalities linked to access to facilities in suburban areas, we want to make recommendations on three (03) periods.

In the short term, i.e., over the next 05 years, we need to accelerate the reduction of carbon emissions from the most widely used modes of transport. These include motorized two- and four-wheelers. This is already underway in Benin Republic, with the introduction of tax exemption for electric vehicles since January 2022.

In the medium term, within the next 10 years, we need to ensure that we reduce the dependency between modes of transport and access to facilities. This approach will enable pedestrians to access the various facilities essential to their daily lives. It would also reduce the frequency of personal motorized transport, which has catastrophic consequences for the environment. Urban planning policies in Benin can be improved on the basis of the results of our work. Firstly, this study shows that the methods used to analyze access to facilities can be improved by giving priority to GIS approaches. GIS can also be used as a basis for choosing the location of socio-collective facilities. Today, in Benin Republic, facilities are positioned according to the number of people to be served, by administrative division, and do not necessarily take into account the ability of residents to access these facilities. To improve access to facilities and reduce the negative externalities associated with transport, urban planning and transport policies need to be redefined. Secondly, it would be wise to think about improving the spatial distribution of facilities and integrating into the existing transport system modes that allow everyone to access services and facilities in an acceptable time.

In the long term, within the next 15 years, to reduce the consequences of the frequent use of personal motorized modes of transport, it would be wise to develop an efficient public transport system in these peri-urban areas in the Republic of Benin. The introduction of this transport system should be preceded by judicious roadway development. Road design must take into account not only mass transit lines, but also and above all active modes of transport (walking, cycling, etc.).

5. Conclusion

Facilities and services are an integral part of human life, and access to them, regardless of financial capacity, modes of transport or geographical location, is essential to ensure social equality. The aim of this study was to assess access to facilities in peri-urban areas in West Africa, based on the districts of Hêvié, Ouèdo and Togba in Grand-Nokoué in the Republic of Benin. We worked to define the facilities most visited by residents, and then looked at the modes of transport used and their speed, in order to define the relationship between modes of transport and access to the various facilities. For the first time, the isochrone approach was used to assess access to facilities in less than 20 minutes in the Hêvié, Ouèdo and Togba districts.

The most common modes of transport in the study area are walking, motorized two-wheelers and cars, both private and informal. Travel speeds recorded for each mode of transport vary according to road surface.

With the strong variation in speed between modes of travel, the possibility of accessing equipment in a time $t \leq 20$ min varies greatly from one mode of travel to another. This study shows that in peri-urban areas as Hêvié, Ouèdo and Togba, access to facilities essential to community life (such as education and healthcare) is uneven and depends on the mode of transport used by residents. Motorized transport users (motorcycles and cars) have privileged access over pedestrians. In the absence of an official public mass transit system operating on the territory, households have to resort to two- or four-wheeled motorized vehicles to access facilities. In fact, two and four-wheeled motorized vehicles are among the main modes of transport used by residents of the study area. In this context of accessibility conditioned by the availability or non-availability of a motorized modes of transport, social inequalities therefore remain strongly present in West African peri-urban areas. On the other hand, access to shopping and leisure facilities is independent of the mode of transport used. Pedestrians and users of motorized modes of transport can reach them in less than 20 minutes. The difficulty of accessing certain facilities is justified by their uneven distribution across the region, requiring residents to travel long distances. Under these conditions, it is very difficult, if not impossible, for certains modes of transport to ensure the population’s access to facilities. In these conditions, it is increasingly necessary to work on finding more accessible and less polluting modes of transport to enable residents of peri-urban areas to access the various facilities essential to their daily lives, in order to reduce social inequalities.

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