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The pursuit of a sustainable and accessible mobility on university campuses

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Abstract

With the enactment of the Brazilian Law Nº 12,587, the National Policy on Urban Mobility (2012), mobility systems on university campuses need to be reviewed according to its principles. The theory is reasoned on urban planning and space syntax in which the urban layout settings generate movement patterns in the city, as well as on campuses. The history of areas intended for university education and weather conditions were addressed. It was concluded that campuses should preserve park characteristics mitigating the decrease of green spaces in the cities. Sustainability concepts should be applied: decrease in the use of individual motor vehicle, encourage cycling and active mobility, in addition to user safety and security, and equity in transportation modes.

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Keywords: University campus; Urban mobility; Sustainable mobility; Urban layout; Urban planning; Road systems; Active transportation.

1. Introduction

Studies on space syntax indicate that both in urban planning and in transportation, patterns of land use influence the conditions of mobility and accessibility of the population and that commutes are not only evaluated by physical distances, but also by the quality of the road system and the use of transportation systems that are environmentally sustainable, comfortable and inclusive. These concepts are especially important to be applied on university campuses because they are areas in which walking and the use of other active modes of transport can be easily stimulated.

With the advent of the PNMU, the National Policy on Urban Mobility in Brazil (2012), the guidelines regulating the aspects of urban mobility were assembled and instituted. This Law has a broad spectrum and aims to provide local administrations with guidelines and instruments that improve good mobility conditions in Brazilian cities.

Based on these two elements of analysis inserted in the context of urban mobility, space syntax and the continuing evolution of legislation, this article seeks to deepen the knowledge of the subject in areas intended for university campuses enclosed in the urban environment. As a hypothesis, it was sought to demonstrate that these

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places need adjustments to reach the current formalities of urban mobility standards, such as equity in the use of different transportation modes, sustainability, universal accessibility, safety and effectiveness in urban traffic.

In order to test this hypothesis, this article took as a reference the study of urban layout of six Brazilian campuses, with the aim of evaluating to what extent the current conditions of mobility and accessibility are close to the guidelines on the subject. This perception emerged with the new inclusive vision in order to enable accessibility requirements on campuses, and an evaluation in this sense was carried out to verify the mobility conditions of these sites.

Road systems of Brazilian federal university campuses were studied, aiming at a comparative analysis of their characteristics and were sought general mobility guidelines that should be implemented on university campuses.

2. Subject matter hereof

After the Brazilian university reform of the 1960s, there were significant changes in the Brazilian educational system, with influences on the configuration of its campuses road systems. The initial plans changed, prioritizing motorized displacements over walking:

> "The campus road system (...) represents the framework of a campus in its earliest days. An original strategy for the vehicle is clearly distinguishable (...) and the pedestrian appears very remotely in the presence of sidewalks installed as components of these same motor vehicle routes" Federal University of Pernambuco (1985, p.43).

From the 1980s, the concept of social inclusion has been inserted in the Brazilian urban context. Laws have been formulated and approved in which citizen access and mobility rights must be equal, regardless of their physical limitations. According to new standards, such as the Brazilian Law NBR 9,050 (2015) - accessibility to buildings, furniture, spaces and urban equipment, promulgated in 1994 and first updated in 2004, is not allowed that people with disabilities face physical barriers on commuting. They should have equal access to transport and the physical environment.

With the enactment of the Brazilian National Policy on Urban Mobility (2012), the instruments in favor of a sustainable and socially fair urban mobility have been implemented. The policy establishes principles, guidelines and instruments so that counties are able to plan a collective transportation system capable of serving the population and contributing to sustainable urban development. The law encourages the prioritization of public and collective transportation, and active modes, rather than individual, private and motorized transportations.

The main objective of the article is to analyze the extent to which the current accessibility and mobility conditions of the campuses under study meet the current requirements of the National Urban Mobility Policy. In order to meet the main objective, the following specific objectives were scheduled:

- Establishment of theoretical references for the analysis of accessible mobility of the campuses under consideration;
- Verification of the law enforcement recommended in the PNMU, on campuses mobility system;
- Conclusions and general advices on mobility in campuses surrounded by the urban network, due to the natural process of growth and conurbation of the cities.

Nowadays, mobility management is one of the biggest concerns of managers in the large urban centres. The increasing usage of individual vehicles is accentuating congestion, lack of parking lots and insecurity of pedestrians and cyclists regarding the danger of accidents. Campuses have the same problem. The growth of the university population and the consolidation of laws that regulate urban mobility motivated the interest for the study of mobility in campuses inserted in urban meshes in constant growth, accentuated by the conurbation process of the great metropolises. The university environment must comply with the regulations and the precepts of the PNMU, providing tranquility and comfort to users in their daily commutes.

Fig. 1. Medieval house. Source: Pinto, G., Buffa, E. (2006, p.3).

3. Origin and evolution of areas intended to the university education

Universities in Europe were born along with the process of urbanization of cities, according to Pinto and Buffa (2006). Schools were integrated into the urban environment and constituted elements of their growth. The earliest medieval educational institutions date from the thirteenth century and had a modest origin, with the aggregation of same craft apprentices in rented rooms or rooms of the masters' own residences, in single or small buildings (fig.1). The territory of the school was defined by its buildings, and around, the city flowed and grew freely.

By the end of the Middle Ages, around the middle of the fifteenth century, due to the growth and enrichment of the cities, buildings for university education were being remodeled, and with that the emergence of colleges, a new category of urban construction:

> "In colleges, the quadrangle is a space surrounded by buildings, usually two stories, with a simple lawn in the center and open circulation around it. In most schools, this space of circulation and leisure (...) allowed internal access to all buildings"
> Pinto and Buffa (2006, p.7).

The spatial organization of these buildings required an appropriate place for book storage. Thus, the library became an indispensable element in the project. What characterizes these buildings is their urban character (fig.2).

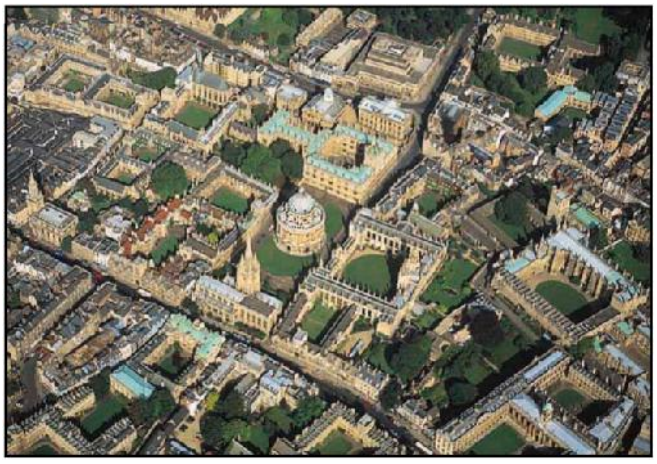

Fig. 2. Aerial view of Oxford (aggregation of colleges and the library at the centre). Source: Pinto and Buffa (2006, p.8).

Fig. 3. University of Virginia, Campus view. Source: Pinto and Buffa (2006, p.11).

The idea of universities or "miniature cities" located beyond the boundaries between city and country came from the American conception of the seventeenth century. Not only classrooms and other academic spaces would be built, but also dormitories, canteens and recreational spaces. The project was not about designing isolated buildings, but an entire community. According to Turner (1984), a new experiment of urbanism in favor of separate buildings, located at an open green space. Thus, the campus became an independent territory, calm, pleasant and equipped to fulfill its objectives.

According to Pinto and Buffa (2006), the first university campus project were conceived by the third president of the United States of America, Thomas Jefferson (*1743-1826+). Jefferson chose a piece of land from an old farm in his hometown, Charlottesville, in the center of the state to establish the University of Virginia. The plan was a longitudinal north-south axis and, perpendicular to it, several other axes demarcated the site of the buildings that made up the campus. At the end of this axis, to the south, the library was built on. A new site was set for teaching: the university campus (fig.3). An unprecedented breakthrough in terms of pedagogical plans and in area intended for university education. Subsequently, it was replicated throughout the USA and in many countries worldwide.

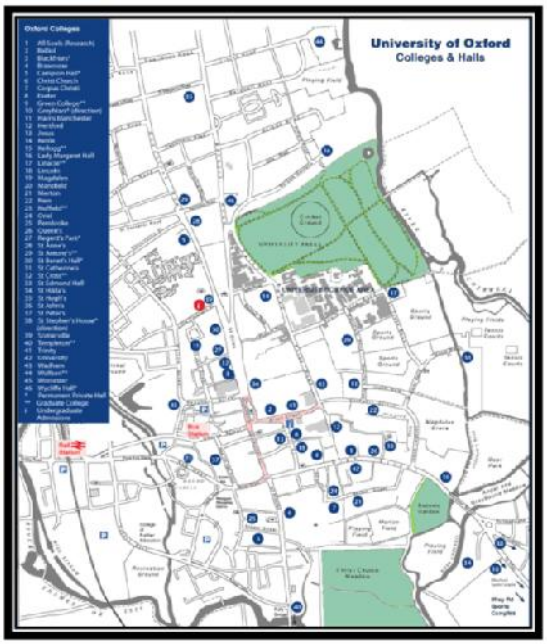

Fig. 4. Oxford University. Source: Pinto, G., Buffa, E. (2006, p.9).

In Brazil, the establishment of higher education schools was made in isolated buildings inside the urban environment, since their beginning until the first half of the twentieth century. Until the end of the Brazilian New State, the main paradigms were those of European cities, such as Cambridge, Paris and Oxford (fig.4). Since 1945, American universities, which have been recognized for the contribution of technological advances, have become the main model for Brazilian universities, including their spatial organization as University City or university campus, according to Cunha (1983).

4. Urban mobility issues on university campuses

4.1. Climatic conditions

Studies carried out by Afsar et al. (2015) approach the urban way of life emphasizing the development of transportation with the objective of preserving the natural environment. At University Putra Malaysia (UPM), planners have attempted to promote active transportation, encouraging walking and cycling as sustainable environmental-friendly transportation, without reducing campus quality. Obtained after a questionnaire answered by pedestrians and cyclists, the environmental influences that were decisive to encourage walking and cycling were presented. Canopies were at the top of the list as extremely important buildings that should be developed and improved as well as bus stop shelters in terms of facility item. The reason for these priorities can be attributed to local climate. Malaysia's climate is classified as tropical, with average temperature of 27°C and 250cm of precipitation per year. In addition, a large number of respondents complained about the lack of tree cover. It was also determined that signs of indicative directions are important, avoiding unnecessary commutes and challenging the decision to find their way.

4.2. Active transportation

Several measures have been taken to mitigate the increase of motorization rate. Among them is the incentive to multimodality in the transport system, including active transportation. Environmental and health reasons support the trend for replacing small urban routes done by motor vehicles by another mode of transport in which the user is active, especially walking and cycling. Any non-motorized vehicle such as velocipedes, skates and skateboards are also considered active mobility. Appropriate measures to promote pedestrian traffic in urban areas are indispensable. Favorable conditions for walking, awareness and respect are fundamental to this practice. In the Brazilian manual of DNIT (2010), on the subject of geometric road projects, is found the following statement:

> "Pedestrian assistance includes public sidewalks, pedestrian crossings, traffic control devices, adaptations of curbs for installation of ramps or lowering the sidewalk level to attend the elderly or disabled people, etc. They also include bus stops boarding and landing terminals, walkways, sidewalks, stairs and access ramps. "
> Brazil (2010, p.94)

The Brazilian Traffic Code (BTC), created by Federal Law Nº 9,503, dated September 23 (1997) establishes rules of conduct, infractions and penalties for road users. Pedestrian and active transportation must be respected and protected by drivers of motor vehicles and have priority in the Brazilian traffic system through adequate signaling and infrastructure in all urban environments, including university campuses.

4.2.1. Bicycle: the leading role

As well as walking, cycling has great potential as an active transportation, especially amongst young people, and represents a symbol of sustainable development in the field of urban mobility. For those reasons, the encouragement of cycling becomes a worldwide trend. It is inexpensive, it does not generate negative externalities and it is self-sustaining because it does not consume fossil fuels. It promotes calorie burning and, according to testimony of users, it brings them joy and well-being. Even with the mandatory prioritization of non-motorized modes and expansion

and improvement of cycle routes, there are still difficulties in attracting a great number of people to this mode of transport in Brazil. With the same mobility problems of cities, universities are increasingly worrying about the overuse of private cars, and at the same time striving to make the campus environment sustainable, according to Páez and Whalen (2010).

In studies on factors of influence in usage of bicycle in trips to universities, Albino and Portugal (2015) describe the role of the campuses leaders:

> "(...) a management that applies sustainable insights, i.e., that values sustainable mobility and the sustainability of the campus environment, favoring active transportation, has a fundamental importance to increase the usage of non-motorized modes. The attitude of users, in this way, becomes the product of a relationship between factors of policy implementation and infrastructure characteristics; the greater the effort of the management body to promote "green" policies, quantified by good bicycle routes, the greater will be the change of users attitude, changing habits to choose modes that improve the health of the individual and the environment. "
> Albino and Portugal, L. (2015, p.10)

The implementation of policies that encourage the use of bicycles in university campuses contributes to sustainable mobility, both in improving access to the campuses themselves and in helping society to pursue healthier lifestyles, transcending the physical limits of campuses.

University campuses should be considered priority areas among the places that deserve incentives for cycling in the urban mobility system. In Brazil and abroad, experiences are being developed on campuses with bicycle rental systems. The main objective of this initiative is the reduction of private cars, motivating users to use a bicycle instead of a motor vehicle. Other purposes are the sustainability represented by the fuel economy and preservation of the environment, reduction of pollution in the atmosphere and soil and the humanization of the academic environment. Prosini et al. (2014) argue on the need to regulate bicycle rental as a public service complementary to urban transportation. Just like in the city, this trend becomes evident on university campuses.

4.3. Geometrical characteristics of the road system

According to the Belo Horizonte Manual of developing road projects (2011, p.77), geometrical project is "the graphic representation of geometrical characteristics of horizontal and vertical road alignments, section or intersection of roads". The basic parameters are the physical aspects of the terrain, such as the land use and topography, and the desired speed and behavior of pedestrians, drivers and vehicles. This project define areas of sidewalks and tracks, islands, beds, additions, recesses, drainage and paving where there must be curb alignments, represented by tangents and curves. The following summarized concepts are about elements of geometric projects addressed in the case study:

- Roads

In line with Article 60 of the Brazilian BTC (1997, p.25), roadways are classified according to its intended use:

1) Fast road - it has special accesses with free traffic, without intersections in level, without direct accessibility to the bordering lots and without crossing of pedestrians in level.

2) Arterial road - characterized by intersections at the level, usually controlled by traffic light, with access to secondary and local roads, allowing traffic between city regions.

3) Collector road – designed to collect and distribute the flow of fast or arterial routes, allowing internal traffic to the regions of the city.

4) Local road - characterized by intersections at the level without traffic lights, intended only for local access or restricted areas.

University campuses must present road hierarchy with mobility and accessibility conditions to ensure adequate circulation to users.

- Sidewalks

There are active transportation pavements that must have adequate flooring for this purpose, with a regular, firm, stable, non-slip and non-tread surface for wheeled devices. Without this condition, users may prefer to displace on roads. It must be guaranteed a free track just for pedestrians, without steps, built along the street.

- Bicycle Paths

On university campuses, it is recommended to increase the road system with bicycle lanes, for its important role as an active mode of transportation. If possible, the sharing of bicycle paths with pedestrians, runners and skaters should be avoided. There is incompatibility among these users due to the differential of speed, besides changing quickly of direction, without time of cyclist's reaction, according to Brazil (2010, p.136).

- Intersections

These geometrical shapes are defined as "confluence, junction or intersection of two or more roads", according to the Brazilian Manual of geometric project of urban crossings (2010, p.34). Intersecting vehicle traffic may merge or intersect with other route(s), form a new stretch or separate into two or more stretches of roads.

Intersections should be designed to avoid or reduce conflict points. Conflict points are places at the intersection where traffic streams cross each other. Intersections are considered critical areas, as they represent greater risks of accidents. At the intersection of four stretches, there are 32 points of conflict, of which eight are divergent, eight are convergent and sixteen are crossing points (fig. 5a).

- Roundabouts

According to Brazil (2010, p.36), "roundabout is an intersection in which traffic circulates in one direction, around a central island". Usually, roundabouts are used when there are five or more road stretches and the crisscrossing movements are tolerable. The roundabout presents a high cost of construction and the need for a large land area. They are suitable when it is necessary to reduce the speed of the highway. They also have advantages such as eliminating crossings, reducing waiting time, low maintenance and operating costs, allowing return maneuvers and reducing fuel consumption and emission of pollutant gases by avoiding sudden speed changes, such as in traffic light intersections (Brazil , ibid, p.136, 432).

In addition to slowing speed down, another advantage of the roundabout is the reduction in the number of conflicts at the intersection. If we consider an intersection of four branches, where there are thirty-two points of conflict, the roundabout will decrease that number to eight (fig.5b).

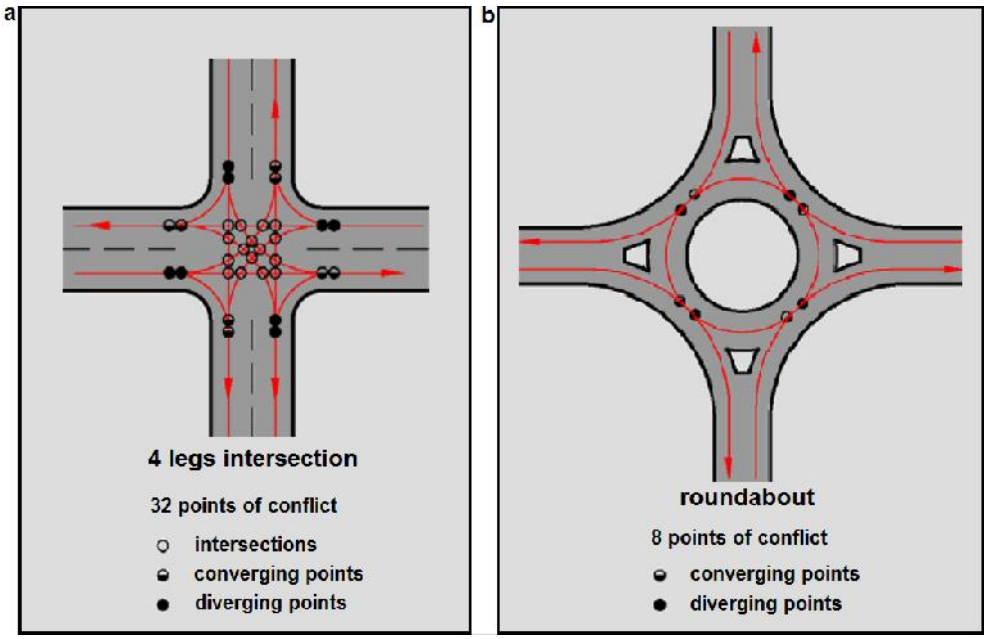

Fig. 5. Points of conflict on a four stretches intersection and on a roundabout with single track. Source: Brazil (2005, p.179). Edited by the researcher in 29/04/2018.

4.4. The theory of space syntax applied in the case study

Space syntax, created in the 1980s by Bill Hillier and his colleagues at the University of London, encompasses a set of theories and techniques for the analysis of spatial configurations of cities, which seeks to represent the configuration of the urban layout and the relation between public and private space through quantitative measures that allow the understanding of important aspects of the urban system, such as: accessibility, land use, social cohesion / exclusion and security.

One of the basic concepts of space syntax is the definition of *natural movement*, which can be understood as the total movement of pedestrians in a network of public spaces, determined only by its configurational path, independent of the presence of attraction elements, according to Hillier (1996). Thus, natural movement is the movement of people determined only by the configuration of streets and squares, by the way the streets are connected or not, if they have continuity, if important connections are made between points in the city and so on. Hillier et al. (1993) argue that the layout of the track by itself, already generates a pattern of movement through the city, and this pattern is the main defining of other elements of the urban system, e.g., the land use. Deepening this point, urban uses are subsequent to the configuration, and act as multipliers of natural movement patterns. Therefore, the number of pedestrians of a location is the product of the combination between the configurational structure and the attraction exerted by the activities carried out in the buildings, such as commerce, residence, industries, etc. Stores, for example, tend to settle in spaces with high integration because these places already have a natural movement of people. This combination starts to motivate a larger number of people, increasing the amount brought by the configuration of the route, accentuating the natural movement. The use always follow configuration, not the other way around. If it is desirable to change land use, an alternative is to change the urban layout.

Another concept of this theory is *integration*, which is the main measurement of Hillier's foundations. It is used to identify areas that have potential to structure and sustain attractive centers. These studies can identify the potential of campuses in exert polarizing forces of attraction in cultural, sports activities, among others. It is advisable that areas of campuses have high values of integration.

In another analysis, Hillier (1996) ponders spatial design can change the structure of consciousness patterns, and lead to pathological phenomena such as the radical reduction of natural movement density. By its power to generate movement, spatial design creates a fundamental pattern of co-presence and co-consciousness, which is the potential encounter amongst people that is the most rudimentary form of awareness of others. Communities have a certain density and structure, and are composed of different types of people: inhabitants and strangers, relative inhabitants and relative strangers, men and women, old and young, adults and children, and so on. Changing the structure of patterns of co-presence and co-consciousness by dominating spaces by unique categories of users can lead to fear and emptying of spaces. In a study carried out by Hillier et al. (1993) in a housing complex in London there was higher incidence of thefts and crimes in areas with low values of integration.

5. The development of sustainable urban mobility policies.

In Brazil, with the awakening of the concern for accessibility and urban mobility, new legislations have been drafted. With the enactment of the Brazilian National Urban Mobility Policy Law (2012), principles, guidelines and instruments for municipalities have been established to plan a public transportation system capable of serving the needs of the population and contributing to sustainable urban development. The law encourages the prioritization of collective, public and non-motorized, over the individual, private and motorized transportation. The principles are set out in the Law Nº 12,587/2012, Section II, articles 5. It is considered interesting the discussion on mobility in university campuses in the following topics:

Article 5 - Principles:

- I - Universal accessibility;
- II - Sustainable development, in the (…) environmental dimension;
- (…)
- IV - Safety in commutes;
- (…)

- VIII - Equity in usage of public circulation area, roads and public places;
- IX - Efficiency and effectiveness in urban traffic.

As a consequence of the principles in the previous article, law guidelines and objectives are set out below, described in articles 6 and 7:

Article 6 - Guidelines:

- (…)
- II - Priority of non-motorized modes of transport over motorized and collective public transport over individual motorized transport;
- III - Integration between modes (…) of urban transport;
- IV - mitigation of environmental and social (…) costs of commutes in the city;
- V - encouraging (…) the use of (…) less polluting energy.

Article 7 - Objectives:

- I - Reducing iniquities and promoting social inclusion;
- (…)
- III - Improving urban conditions of accessibility and mobility for the population;
- IV - Promoting sustainable development by mitigating the environmental (…) costs of commutes(…) in the city.

6. General historical characteristics on Brazilian campuses

From the 1950s, the establishment of Brazilian university campuses in the cities is similar. The State expropriates or receives by donation an area far from the center of the city, with low demographic density and it elaborates urban and architectural projects. With the evolution of urbanization and the phenomenon of conurbation, the constantly expanding urban and road network are surrounding these areas. These open, equipped and independent spaces represent advances in terms of urban planning and should be preserved as they represent areas specifically planned for academic purposes in suitable and integrated environments. The preservation of these spaces and the urgency of modernization to incorporate new concepts of mobility, inclusive and sustainable accessibility are important.

It was never intended to build small independent cities on Brazilian campuses. The surroundings of the universities function as providers of needs that the campuses do not provide or provide below demand to their users, such as housing, food supply, restaurants, commerce and services.

When university campuses are located within the central region of the city, these higher education institutions are either privately owned or state-owned, or were founded before the federalization of 1961, by unification of several colleges and schools built next to each other, in most cases.

The increase of buildings promoted the densification of built-up area in campuses. Despite mobility problems, it has brought certain benefits. This densification generates integration and security to users. On the other hand, it makes mobility more difficult, because of the increased number of individual and collective vehicles, pedestrians, cyclists and disabled people circulating in the same urban space without necessary adaptations, both qualitative and quantitative. It causes more traffic, congestions and shortage of parking spaces, and increases accident risk inside the campus site.

In Brazil, the original US proposal for the independent university campus plan was submitted to modifications and adaptations according to specific conditions of each location. Thus, several typologies of road systems were designed to connect learning and researching buildings on campuses. In their first studies, Prosini et al. (2016) carried out an analysis on the theme about the implementation of four campuses in Brazilian cities.

7. Methodology

In this study were applied the inductive approach and the monographic procedure methods. Also, intensive and extensive observation techniques according to Lakatos and Marconi (1992). In the extensive observation technique, a form was made to facilitate data collection of the six Brazilian campuses road systems (Prosini, 2017, 190-201), each with its own specific characteristics of morphology and mobility.

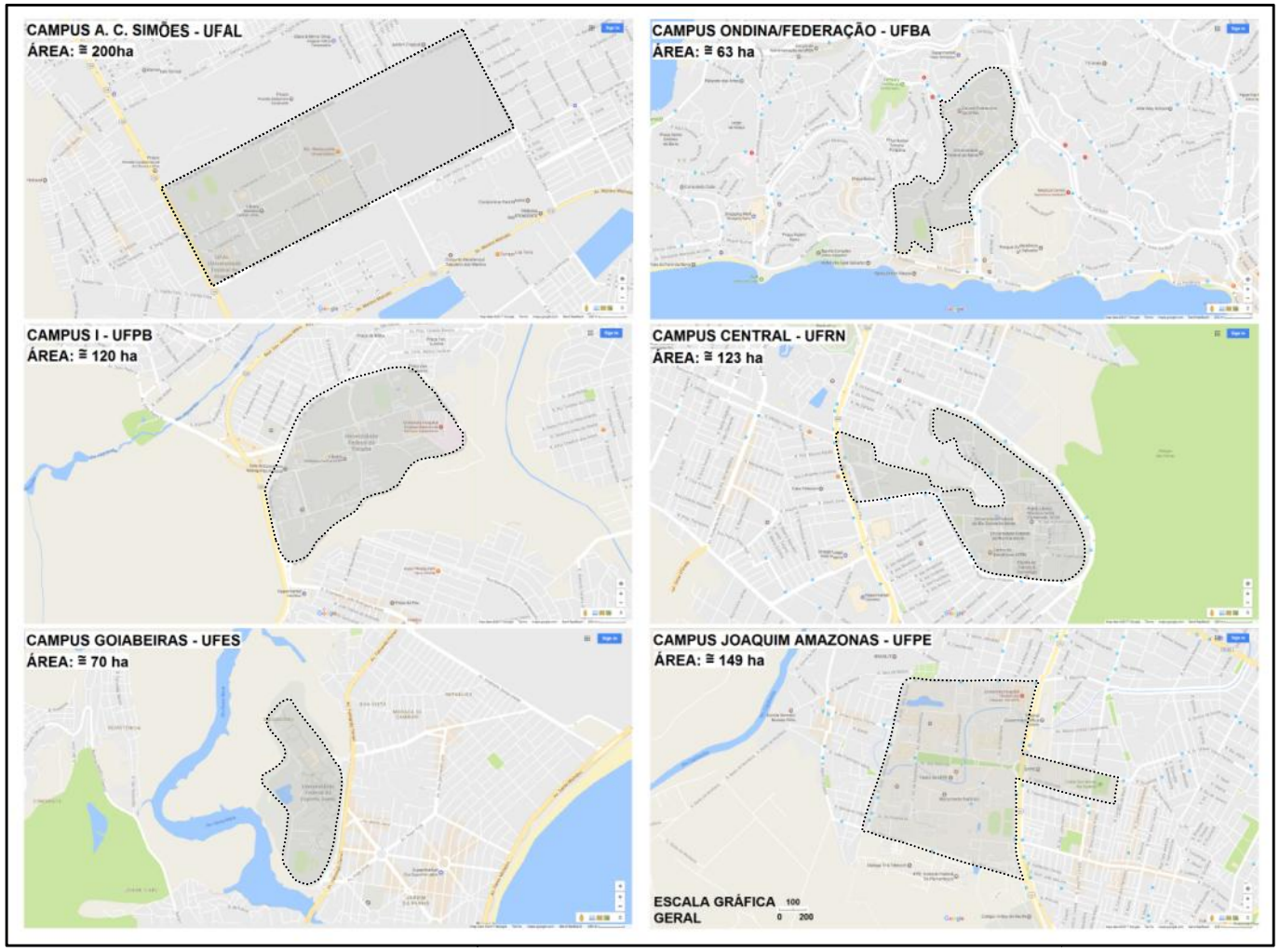

Fig. 6. Campuses maps under same graphical scale. Source: Google Maps (2016). Edited by the researcher in 3/23/2017.

8. Morphological and mobility analysis of urban layouts on Brazilian campuses

In this case study, six Brazilian campuses were selected, each having their own urban layout characteristics. Initially, the maps were gathered in the same graphic scale for comparative visualization of areas (fig.6). They are:

- Aristoteles Calazans Simões Campus from Federal University of Alagoas - UFAL, in Maceió/AL

On A. C. Simões Campus (fig.7) the road system consists of a central axis distributing perpendicular paths that give access to academic units, the same standards of the first university campus idealized by Thomas Jefferson. The rectangular and flat terrain has favored this urban layout solution. A protective metal fence surrounds the university campus. Despite being surrounded by urban network, the insulation of the Campus should be preserved, because it prevents transit traffic in its area, meeting the precepts of the Brazilian PNMU (2012), article 5, principle IV - which values safety in commutes and pedestrian traffic. The construction of a parallel road to the main road causes crossings, making the site unsafe for pedestrians, cyclists and motor vehicles commutes. In this item the solution violates the precepts of the Law (ibid) provided in article 5, principle IX – which advocates efficiency and effectiveness in urban traffic.

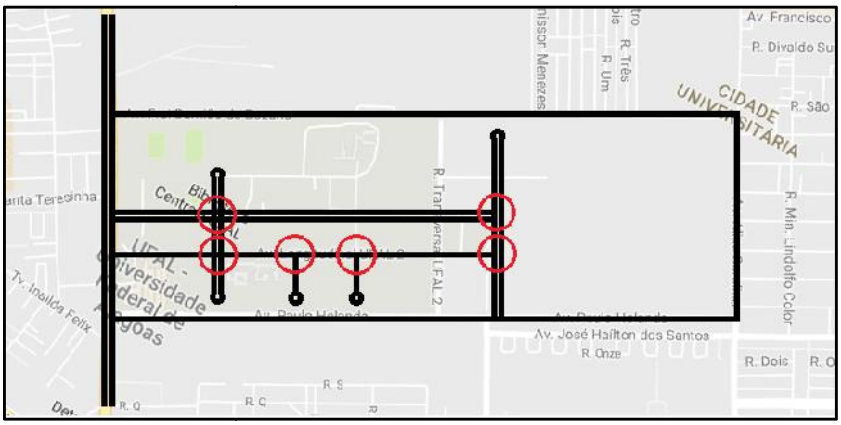

Fig. 7. A. C. Simões Campus urban layout sketch. Source: Google Maps (2016). Edited by the researcher in 3/23/2017.

- Ondina/Federação Campus from Federal University of Bahia - UFBA, in Salvador/BA

The Ondina/Federação Campus (fig.8) has a geographically rugged area. The architectural design of the buildings was essential to improve access, with stairs and elevators that overcome different levels in various locations. As for the road system, there is a central axis distributing traffic. This is a winding road that accompanies the average height of the terrain to avoid large unevenness for traffic of vehicles, pedestrians and active transportation, according to Prosini (2017). There are no intersection routes with the main axis, showing general good results in terms of mobility, but adaptations in terms of accessibility are still required. Therefore, some external stairways linking educational units do not meet the principle I of article 5 of the PNMU, Brazil (2012). Cyclists, elderly and disabled people are not able to carry out these courses because there is no safety or accessibility in these stairwells. Compliance with the precept of modal equity in transport modes is absent on this Campus, concerning the provisions of article 5, principle IV, that preaches safety in commutes, and also principle VIII that advises equity in the use of the public area of circulation, roads and public places. In the other hand, this campus offers plentiful tree cover, emphasizing the development of transportation with the objective of preserving the natural environment as was observed in Afsar et al. (2015) case study.

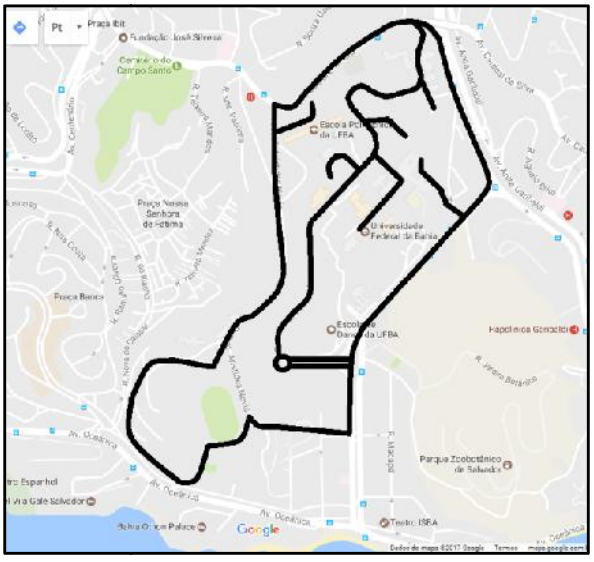

Fig. 8. Ondina/Federação Campus urban layout sketch. Source: Google Maps (2016). Edited by the researcher in 03/24/2017.

Fig. 9. Campus I urban layout sketch. Source: Google Maps (2016). Edited by the researcher in 03/24/2017.

- Campus I from Federal University of Paraíba - UFPB, in João Pessoa/PB

In Campus I (fig.9), the road system consists of an outer ring road, which isolates the Campus from the urban area. The urban surroundings privileges the campus location, as the Jaguaribe River basin and the city's Botanical Garden border the area. Internally, a road composition arranged in perpendicular axes generates internal crossings. In this case, the solution was to build mini-roundabouts that reduce the number of cross conflicts where they were installed. A review is needed in this urban layout, because is necessary to improve safety in commutes and efficiency and effectiveness in urban traffic, in accordance with the principle IV, article 5 of the Law.

On this campus it should be noted the preservation of native Atlantic Forest, providing sustainable development in environmental dimensions, as preaches the principle II, article 5 of Brazilian Law Nº 12,587 (2012), due to the presence of tree cover that stimulates walking and cycling.

- Lagoa Nova or Central Campus from Federal University of Rio Grande do Norte - UFRN, in Natal/RN

Similar situation occurs in the Central Campus (fig.10), with worse context, because the number of intersections is greater in equivalent areas. Inside Campus I, with an area of approximately 120 hectares, there are four mini internal roundabouts, while in Central Campus, with 123 hectares, there are six. The presence of residential area and sewage treatment plant inside the campus ring road complicate the mobility solutions, as it assigns to the site a dispersed and irregular shaped area. The campus is isolated from the urban environment by a metal fence.

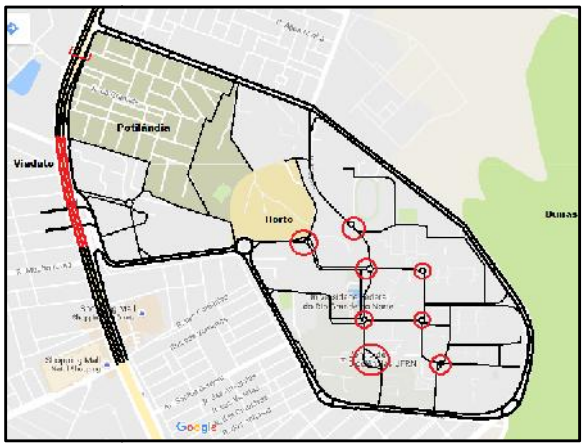

Fig. 10. Central Campus urban layout sketch. Source: Google Maps (2016). Edited by the researcher in 03/24/2017.

Fig. 11. Goiabeiras Campus urban layout sketch. Source: Google Maps (2016). Edited by the researcher in 03/24/2017.

- Goiabeiras Campus from Federal University of Espírito Santo - UFES, in Vitória/ES

Goiabeiras Campus (fig.11) has the best urban layout solution among the six case studies. The layout configuration consists of an outer ring road that allows direct access to the buildings. As for the functioning of the road system, traffic flows in a one-way road clockwise by the boundary ring road Campus, which distributes it to accesses and parking lots of the university. This urban layout pattern avoids intersections and passages through the area, ensuring safety and accident prevention. The basin of the Santa Maria River blocks the urban network sprawl towards its north, south and west directions, providing this distinct location to the Campus. Isolated from the urban network in the greater extension of its territorial boundaries, the security system is simplified, but limited to the accesses of the Avenue Fernando Ferrari. In addition, it provides quality of life to the academic environment. This urban layout provides safety in commutes, equity in the use of public area circulation, roads and public places, and efficiency and effectiveness in urban traffic. In this way, the principles IV, VIII and IX of article 5 are met.

- Joaquim Amazonas or Recife Campus from Federal University of Pernambuco - UFPE, in Recife/PE

Joaquim Amazonas Campus area (fig.12) is represented by a quadrilateral with a longitudinal extension located to the east of the terrain. The road system is made of an external road ring, composed of four routes: to the east, Mário Covas Highway or BR-101; to the north, Professor Arthur de Sá Avenue, to the west, Acadêmico Hélio Ramos Avenue; and to the south, Professor Luís Freire Avenue. In initial plans, there was integration of the University with the local streets. Currently, the area has been isolated from the neighborhood, reducing passing traffic. It was designed an internal road circuit, currently operating in one-way traffic, distributing transit flow. With this configuration, the objective is to eliminate intersection of roads within the university area. In the current situation, there are two points of convergence and two points of divergence, generated by the Reitores Avenue and Joaquim Amazonas Avenue, which make up the central axis of UFPE. The external roundabout, main car access, represents the main intersection of the campus road system. Mario Covas Highway was elevated in this stretch, due to the construction of viaduct, which diverts part of vehicles' flow. There are two alternative secondary accesses to the Campus, a solution to reduce traffic at the roundabout on highway BR-101 or if is not possible to go to the roundabout in case of an accident or blocked roads.

Fig. 12. Joaquim Amazonas Campus urban layout sketch. Source: Google Maps (2016). Edited by the researcher in 03/24/2017.

9. Results and advices

9.1. Specific findings

As a result of the research, strengths and weaknesses of mobility were observed on campuses road systems. UFAL Campus has excessive intersections in its layout, making unsafe commutes to pedestrians, cyclists and motor vehicles. Ondina/Federação Campus has accessibility problems because of the uneven terrain, partially solved by the buildings architecture. Aside this fact this campus has no major mobility problems. UFPB and UFRN Campuses also have excessive intersections. The trouble is attenuated by the existence of roundabouts and because they are located more distant from each other. Goiabeiras is the campus closer to the current Brazilian mobility parameters. Joaquim Amazonas Campus presents some mobility and accessibility issues. The biggest are four intersections in the road system, being two convergences and two divergences on the central road axis.

9.2. General findings

In addition to the specific campuses results, general patterns of mobility and accessibility were detected and deserve attention. There is a need to encourage active transportation and integration of accessibility and mobility, promoting equal conditions for the various modes of transport, an important rule of PNMU (Brazil, 2012). According to it, everyone, including elderly people, pregnant women and disabled people should have equality in their commutes. Sidewalks must be adapted, contributing for an accessible mobility. Mild climate, provided from proper landscaping and shading, is important for the active transportation, in addition to humanizing the environment and promoting sustainable mobility. Intersections must be avoided on campuses road systems, favoring pedestrians, cyclists and drivers safety. For the same reason, car accesses must be reduced to promote protection against vehicle and patrimony theft and reduction of car journeys on-campus. It is important the mildness of car numbers, car velocity, and definition of road directions and its restrictions in active transportation places: leisure, sports and culture areas.

9.3. Advices

For the purpose of achieving the objectives listed in Article 5 in the Brazilian Federal Urban Mobility Law (2012), the following advices for campuses are:

- The merging of the concepts of accessibility and mobility so that current norms of the PNMU (ibid) are met. According to this viewpoint, it is not enough commuting people. It is necessary to guarantee accessibility and mobility isonomically, i.e., any individual, such as the elderly, pregnant women and disabled people must have equity in their daily commutes;

- Sidewalks must be adapted to the principles of the universal design, according to Connell et al. (1997);

- Shaded areas have an important role to ensure pleasant climate for active transportation, in order to create more pedestrian friendly campuses (Afsar, Yunos and Yusof, 2015). Good example of natural tree shading can be observed at Tongji University, Shanghai/China (fig.13c). Covered walkways for sun protection and against bad weather are another way of climatic mitigation that shows positive results in Brazil, such as the Castanheiras Campus in Belém, Pará (fig.13a, b);

- Intersections in campuses road systems should be avoided, favoring physical safety for pedestrians, cyclists and drivers;

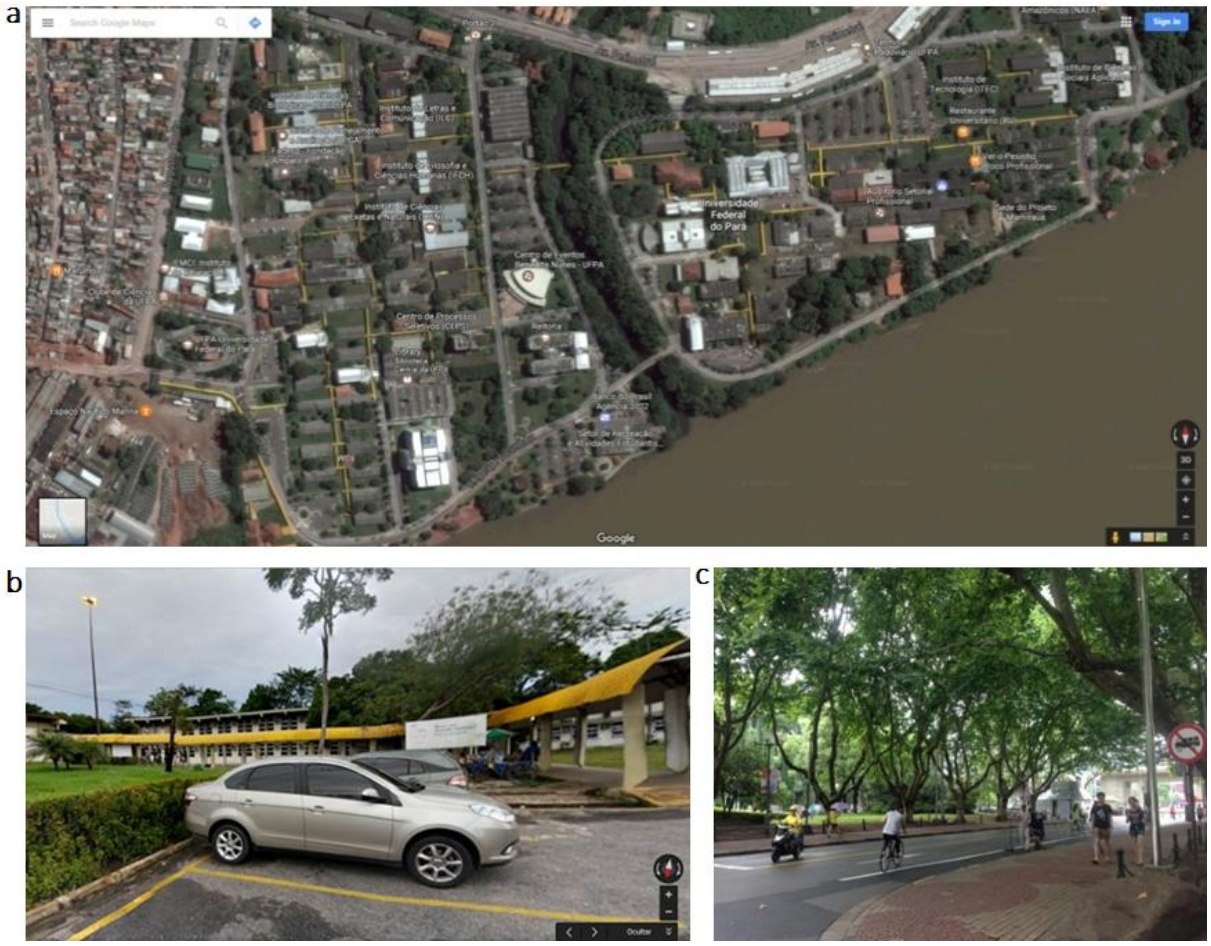

Fig. 13. (a,b) Covered pedestrian walkways on UFPA/Brazil; (c) natural shading on Tongji University, Sipping Campus, Shanghai, China. Source: (a, b) Google Maps (2016); (c) researcher's collection (2016).

- Car accesses: another element to be reduced on campuses. Thus, the site is better protected against vehicles and property thefts. In addition, with several entrances and exits, campus road system may be used as a shortcut in the city, intensifying internal traffic and making the area vulnerable to accidents;

- Encouragement and support measures to the implementation of active transportation on campuses, such as the expansion and improvement of cycle and walking routes, besides agreeable climatic conditions. The increase in the number of vehicles concerns the academic community in relation to sustainable development on campuses.

10. Conclusions and suggestions for future researches

When urban planning is directed towards promoting universal accessibility, active transportation, security to the user, safety by preventing accidents, and mitigating adverse weather conditions for pedestrians, effective ways to improve mobility on campuses are achieved.

Changes in the urban layout can modify the natural movement pattern of campuses. As these patterns are the main defining of urban system elements (Hillier et al., 1993), these adjustments will lead to changes in land use. These changes may bring positive aspects, such as increasing of security and social cohesion through spatial configuration, when deserted areas are reduced or eliminated, and improvement in aspects of accessible mobility and redistribution of land uses. Regarding Hillier concept of integration as a mode of analysis of centralities (1996), it should be borne in mind the potential of campuses as centralizing areas in the urban environment, such as scientific, cultural, recreational and leisure centers in the city. So, we suggest space syntax studies regarding potential functions on campuses as centralizing area on the urban environment.

Mobility and accessibility aspects are studied in a generally way. It is suggested to analyze these aspects with the perspective of areas intended to university education with park characteristics, and all its components: sidewalks, bicycle lanes, cars, leisure areas, among others. Including elaboration of specific rules of mobility and accessibility for campuses.

As proposals for future researches, we suggest studies in other campuses on possibilities of improving mobility, which includes accessibility parameters, modal equity and sustainability. Sustainability involves development promoting environment-friendly use, using non-polluting resources intelligently, such as clean and renewable energy for transportation and preservation of green areas.

It is also of utmost importance the concern about sustainability, disciplining and moderating the excessive presence of motor vehicles on campuses. This implies in decrease of fuel consumption and environmental pollution. The adoption of sustainability measures guarantees in the medium and long term good conditions of preserving life on the planet, guaranteeing quality of life for future generations.

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