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Special Economic Zones vs. Sustainable Mobility

Measuring Movement in Special Economic Zones and Their Context

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ABSTRACT

This research analyses Special Economic Zones (SEZs) from a spatial perspective. SEZs are "legal mechanisms that governments implement to encourage direct foreign investment, exports, and the development and dynamization of the countries' economies." (PROCOMER, n.d., p. 1) They enjoy exclusive economic policies (Farole & Akinci, 2011), resulting in areas characterised as large and usually fenced-in (Pujol Mesalles, et al., 2012; Farole & Akinci, 2011).

Costa Rica, as the case study area, has been acknowledged for its SEZs' success in: reducing unemployment, promoting exports, boosting the local economy, and raising environmental awareness (Monge-González, et al., 2005). Existing policies and research focus mainly on their financial, social, and environmental aspects. Less emphasis has been placed on their spatial context, leaving aside their contribution to promote sustainable urban mobility. Overall, research on the urban impact and spatial dynamics of SEZs has been insufficient.

To address this research gap, this project measures the urban performance of a sample of SEZs located in the Greater Metropolitan Area (GAM) of Costa Rica. The results show that SEZs distribution is characterised by their proximity to the highly accessible streets, both globally and locally. Also, land uses in their context are diverse and spread according to how accessible the spatial network is. A strong relationship is also demonstrated between the spatial network and the types of land uses studied. The Space Syntax methods this study adopts allows Costa Rica and other countries to understand the urban performance of SEZs and their role in sustainable mobility.

KEYWORDS

Special Economic Zones, Space Syntax, Land Use, Movement Economies, Sustainable Mobility

1 INTRODUCTION

Special Economic Zones (SEZs) are regarded as areas that enjoy exclusive economic benefits implemented by governments to help boost their economy. The first SEZ was establish in Ireland in the late 50s, and by the 1970s, SEZs started to proliferate universally and continue to do so (Zeng, 2019; García-Cáceres & Ospina-Estupiñan, 2017; Easterling, 2014). They are policy tools used globally by developed and developing countries, hence definitions and uses vary widely.

Countries and regions adopt SEZs to: (1) attract direct foreign investment to promote exports and industrialisation; (2) help alleviate large-scale unemployment; (3) pursue economic reform strategies; and (4) become laboratories for new experimental policies and approaches (Farole & Akinci, 2011, pp. 3-4; Zeng, 2019, p. 3; FIAS, 2008, p. 12). In reality, SEZs range from industrial and technology parks, to areas full of manufacturing factories, to free-trade zones, to entire cities or city-states with populations of millions (Farole & Akinci, 2011; Lane, 2020; Easterling, 2014; Zeng, 2019). In summary, these characteristics differentiate a Special Economic Zone from other industrial land uses.

Despite the broad range of definitions of SEZs and their application, one thing remains constant: SEZs are policy tools capable of shaping the economy and therefore the society in which they are implemented – either for better or worse. Research on how these tools affect the economies and their communities is extensive, and examples on whether they are successful or not differ. Moreover, there is no scientific consensus or standard formula amongst policy-makers to measure their success. Most studies focus on the cost-benefit invested by governments on the implementation of SEZs, and on their economic, social or environmental performance – Did they achieve the economic goals for what they were initially set? Are they an inequality contributor? How much do they pollute?

Nonetheless, the urban performance of SEZs in their contexts has been little explored, and the spatial input in the literature reviewed is mostly limited to descriptive characteristics. This paper aims to strengthen the conversation around the spatial impact of these zones to bring new research into the field. The study aims to explore the SEZs' urban mobility performance by combining land use insights with space syntax methodologies on a comparison of car and pedestrian measures.

As an analytical theory, Space Syntax provides insight into the changes of the urban fabric configuration. Space Syntax studies the spatial networks connection and how this might influence people's movement within the urban realm (Hillier & Penn, 1996). The street network structure

determines movement, and because streets shape movement they also generate a land-use pattern. The idea is to study the SEZs' impact through the analysis of the street network and land-use patterns. This will help develop understanding of their performance on whether they enhance or hinder sustainable mobility where they are being implemented.

The case of Costa Rica, a Latin American country that has been implementing SEZs since the early 90s, was selected to apply the assessment. Costa Rica is considered a successful case of SEZs implementation in terms of its cost-benefit: they generate more than 40% of the national exports, have increased employment opportunities, wages, and innovative knowledge – especially for skilled workers –, have a strong commercial linkage with local suppliers, and contribute more than 7% to the country's gross domestic product (PROCOMER, 2019; Monge-González, et al., 2005, pp. 3-4). The assessment will help to comprehend if SEZs in Costa Rica promote sustainable urban mobility the way they promote economic and social growth.
In order to achieve this, the objectives of this research paper are the following:

1. Understand the relationship between the location of SEZs and urban movement in the spatial network. Are they accessible for vehicles and/or pedestrians?
2. Describe and test how land uses are distributed around a catchment of 800m of each SEZs.

This paper is based on three Space Syntax methods. First, a spatial accessibility analysis focusing on the measure of Choice (NACh 5000 m– vehicular, and NACh 800m – pedestrian) in a model of the street network to understand the area's mobility patterns. Then, a catchment analysis of the SEZs was performed to determine their reach into the network. This is followed by a land-use analysis, taking into consideration five different uses to define the dominant ones. Finally, statistical analysis to test the relationship between spatial accessibility and the different land uses studied.

2 THEORY

2.1 The Global Definition of SEZs

SEZs are challenging to define due to their variety. According to FIAS – the multi-donor investment climate advisory service of the World Bank Group – (2008, p. 9), the concept of SEZ can be simplified as: usually fenced-in or somehow delimited areas, managed by a single administration, eligible for benefits once located within the physical zone, and with taxation or duty-free advantages. Moreover, SEZ have been described as large areas of at least 50 hectares or more (FIAS, 2008; Farole & Akinci, 2011) that tend to have access to ports (Lane, 2020; McCalla, 1990). They can be enlisted – yet not limited to – as follows: free-trade zones (FTZ), export-processing zones (EPZ), industrial parks, economic and technology developments zones,

high-tech zones, science and technology parks, free ports, enterprise zones, and hybrids in between (Zeng, 2019; FIAS, 2008; Farole & Akinci, 2011).

With the proliferation of SEZs globally, questions on whether they are effective instruments arise. There also seems to be a lack of a standardised method to measure their success, and the literature reviewed points to assessments mostly focused on their economic, social or environmental performance. Zeng states that normally the *success* of a SEZ "depends on whether it meets the objectives defined when it was established (generally for a time horizon of 10 to 15 years), and whether it is commercially viable in relation to the total investments in the [endeavour]" (2019, p. 3).

Some scholars (Easterling, 2014; Lane, 2020) claim SEZs are mere instruments that benefit only multinational corporations (MNCs) "with incentives like tax holidays and cheap [labour]" (Easterling, 2014, p. 22). Usually, the reason given by governments to attract these MNCs is the generation of jobs, and thus a rapid alleviation to unemployment. Other criticisms include not producing enough earnings with exports; pulling investment away from poorer and segregated areas and concentrating only in wealthy urban metropolis (Lane, 2020, p. 154); failing to remain feasible when labour costs risen and former advantages decline; and the risk of SEZs becoming enclaves with no connection beyond their fences nor with the local economy (Farole & Akinci, 2011; Zeng, 2019). This last statement is investigated further in this paper: To what extent do the SEZs' connection to the city network reflect a sustainable relationship to the city itself or not.

On the other hand, empirical research (Monge-González, et al., 2005; Farole & Akinci, 2011; FIAS, 2008; García-Cáceres & Ospina-Estupiñan, 2017; Zeng, 2019) has also recognised the success of some SEZs on "generating exports and employment, and come out marginally positive in cost-benefit assessments" (Farole & Akinci, 2011, p. 4). Among the benefits pointed to SEZs are: the key role they play on modernising trade trends; diversification of the industrial development; upskilling of the local population; and even improving the tax situation of some countries (Monge-González, et al., 2005; García-Cáceres & Ospina-Estupiñan, 2017). In this research the SEZs' location is examined given that it must add to achieving these successful features.

2.2 The *Successful* Case of SEZs in Costa Rica

Costa Rica is a Central American country, bordering Panama to the South, and Nicaragua to the North (see Figure 1). It has a population of about 5 million inhabitants, and a national Gross Domestic Product of around USD$61 million by 2020 (The World Bank, 2022). Its capital is San José, located in the Central Valley and also known as The Greater Metropolitan Area (GAM according to its acronym in Spanish) – the main urban development of the territory and where most SEZs of the country are located. The GAM stands out for its high population density, as well as for its exponential increase of economic activities. It has expanded to the extent of

merging the main cities of four out of the seven provinces that divide the country: San José, Cartago, Alajuela, and Heredia (Figure 1).

As mentioned before, Costa Rica is considered a successful case of SEZs operation from a cost-benefit perspective (Monge-González, et al., 2005). Those industries categorised as SEZs produced 43% of Costa Rica's exportation goods between the period of 2014-2018, and generated 115,000 new jobs in 2017 (PROCOMER, n.d.). The country defines SEZs as "legal mechanisms that governments implement to encourage direct foreign investment, exports, and the development and dynamization of the countries' economies." (PROCOMER, n.d.). It implements a hybrid Export Processing Zone (EPZ) model, described as zones "typically sub-divided into a general zone open to all industries regardless of export orientation" (FIAS, 2008, p. 10). According to PROCOMER (n.d.) a non-governmental Costa Rican public entity, SEZs in the GAM are categorised into the four typologies of industry: (1) Manufacturing in Strategic Sector; (2) 100% Export Marketer; (3) Strategic Sector Services; and (4) Industrial Parks Administrators. The distinction among the four typologies of SEZs consists of the differentiation of each of the goods these zones produce.

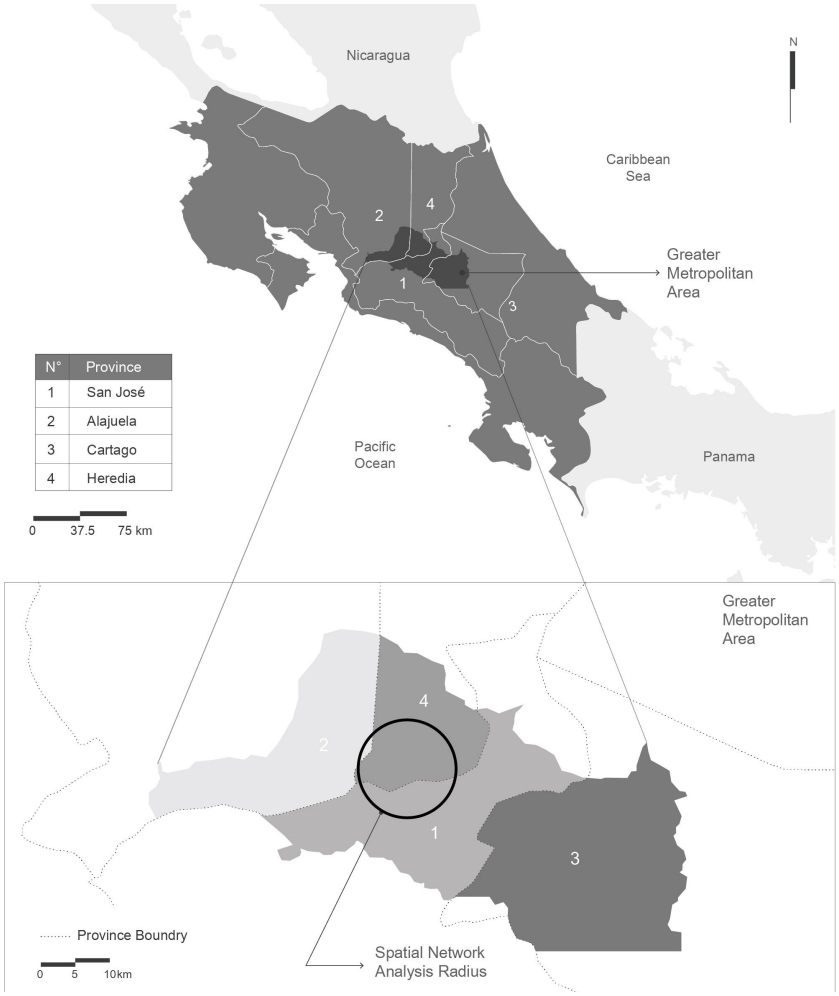

Figure 1: Map of Costa Rica highlighting the Greater Metropolitan Area and the provinces it covers as a result of its extension. At the bottom: the Spatial Network Analysis' Radius for this study, shown with a black circle.

According to Manuel Castells (1999), during the 80s and 90s, the GAM endured changes in the organisation of economic activities and the shaping of the labour market. One of the reasons why the economic model in the GAM has grown is due to the establishment of SEZs. They have attracted foreign direct investment, brought great financial benefits for the country, and configured a new geographical model of mobility and centrality in the GAM.

The location of SEZs have undergone changes since they started to flourish in the early 90s. At the beginning of the 2000s, the SEZs were located in different districts of the four provinces, with some upholding more industries than others and not necessarily close in proximity with each other. In the last decade, the development of SEZs has expanded more to sites outside San Jose (Pujol Mesalles, et al., 2012), because there is already industrial saturation in that city and the rising transaction costs associated with road barriers, transportation costs and over-processing (Arias Ramírez & Sánchez Hernández, 2012). Nonetheless, some SEZs still remain located in the capital. This has led to zones developing mainly in the provinces such as Heredia and Alajuela, which have areas of industrial occupation that exceed 24% and 22% of their territory, respectively (Central America Data, 2016). These areas have advantages such as accessible land value and strategic location to air and seaports. For these reasons, the area of study of this paper encompasses SEZs located between Heredia, San José, and Alajuela.

The SEZs require large areas, access to specialised public services, and reasonable proximity to their workers. For these reasons, they seek to establish themselves in areas that will enable them to comply with these characteristics (Pujol Mesalles, et al., 2012, p. 200). They can be located in fenced-in areas (Pujol Mesalles, et al., 2012), identified as “Industrial Parks within Parks”; yet registered EPZ enterprises can also locate themselves in areas that share other regimes (FIAS, 2008, p. 10), identified as “Industrial Parks outside Parks” (PROCOMER, n.d.).

According to the requirements established by PROCOMER (n.d.), there’s a minimum foreign investment and employment that needs to be generated for the companies interested to be part of the SEZ. In regards to urban, environmental, and sanitary regulations there are no specific regulations or standards that foreign industries must need to follow to be emplaced.

2.3 Sustainable Urban Mobility

The term urban sustainability is understood in this paper as cities or urban spaces that strive for social equity, ecological protection, and economic viability; in other words, those spaces that perform positively in the social, environmental, and economic dimensions (UNDP, 2021) . According to the Sustainable Development Goal 11 of the United Nations Development Programme (2021), sustainable cities and communities should, amongst other things, account for sustainable ways of mobility, and easy access to housing, work, services, and green and public spaces for all. Mobility and movement in cities are an extensive field of study due to the

complexity and the many edges the phenomenon touches. They play a pivotal role in the access to life-enhancing opportunities (Akyelken, 2017), and socioeconomic systems and their development patterns depend on them (Raco, 2007) because it allows or hinders both people and goods to reach places in the city.

SEZs, as sources of employment and producers of exports, function as generators of movement within cities. Research has suggested that SEZs tend to locate where workers can access them efficiently (Pujol Mesalles, et al., 2012), and where the transportation of the products is easily connected to ports (McCalla, 1990; Lane, 2020; Espinoza Reyes, 2020). When it comes to the case of Costa Rica, a strong car-centric system still prevails. The country's available infrastructure to transport goods and exports is a network of motorways and roads that connects the GAM, and therefore the SEZs, to the main ports – the main international airport, the Caribbean port Moín, and the Pacific port Caldera. Moreover, the use of private cars for short trips within the GAM is still the preferred means of transport, above public transport and active mobility. The GAM has been considered as an area where the time invested by people travelling is particularly extensive, despite being one of the least dense cities in Latin America (MIDEPLAN, 2020, p. 4). Thus, the GAM can be described as heavily motorised and with a low degree of active mobility, where its population spends elongated intervals transiting to reach their workplaces, services, households, and recreational spaces.

Regarding the environmental repercussions of transport and movement, research has vastly demonstrated that motorised transportation, especially private cars, have a negative impact on the environment and health (Pisoni, et al., 2021), as it "has already been identified as the fastest-growing source of greenhouse gas emissions" (Czech, et al., 2021, p. 1). Hence, implementing active mobility in urban spaces (e.g., walking and cycling) has become a priority as it contributes to the environment by mitigating CO_2 emissions, but also reduces overweight and obesity in the population (Pisoni, et al., 2021). Active mobility is currently seen as a key factor for cities driven by sustainability principles.

Land use patterns of development can determine the success of active mobility in cities. The principle is simple: the more mixed the uses are in an area the more likely it is that people choose walking or cycling to reach different places. Lawrence Speck (2014, p. 27) explains:

> *"In a very elementary sense, mixed-use development is just practical. It places the day-to-day things we need to do in immediate proximity to each other. Less transportation is required for daily life, and thus the massive amount of consumption associated with transportation is [minimised]."*

On the other hand, monofunctional vast areas mean longer distances, and therefore more transportation required, reinforcing a higher preference for private cars to travel. As mentioned

before, some SEZs in Costa Rica are considered to be large areas sometimes bigger than 50 hectares (FIAS, 2008; Farole & Akinci, 2011) – mainly single land uses of industry. This raises the question on whether this characteristic of SEZs may force their workers to opt more for motorised means of transport instead of active mobility.

2.4 Space Syntax and the Movement Economy Theory

Space Syntax explains the configuration of cities as networks of space. The combination of the spatial network with its social and economic characteristics has been studied by Hillier in the "movement economy theory". Hillier and Penn (1996) explained the adaptability of the land uses or activities within cities according to the flow of movement in the street network. The *movement economies* theory states the relationship between the physical city – "buildings, space, infrastructure" – and the functional city – "economic, social, cultural, and environmental processes" (Hillier, 2007, p. 111). This relationship understands the city as a whole in terms of space and functionality (Hillier, 2007), which intends to contribute to live and build a sustainable city. Besides, the people's movement is believed to be the determinant factor influencing both the physical and the functional city.

People's movement patterns shape the city's spatial configuration. These patterns are tied to the intelligible – "an intelligible system is one in which well-connected spaces also tend to be well-integrated spaces" (Hillier, 2007, p. 94) – perception that a city's inhabitants have of their milieu (Hillier, 2007). Vehicular and pedestrian flows will follow the intelligible space at different scales; the flow will thus affect the land-use choices. For example, the more intense pedestrian flow, the more likely retail and mixed-use buildings will prevail. This land-use density in turn, will attract more people in a multiplier effect in which the urban grid's structure benefits from people's movement patterns and the other way around.

Movement economies are directly linked to human mobility, land-use and building density, the network spatial configuration, and consequently to sustainable urban mobility. For the SEZs to be sustainable within the network configuration, their location and interaction with the immediate context should follow the principle of movement economies.

2.5 Space Syntax and Sustainable Mobility

Sustainable mobility is often associated with walkable cities that provide enough access to a variety of services and amenities to the population living nearby (Santilli, et al., 2021). Also, as stated before, the mixed-use assist to achieve this purpose. Space Syntax measures such as integration, choice and connectivity values have proved to aid when evaluating walkable sustainable environments (van Nes, 2021) (Santilli, et al., 2021) (Hillier, 2009). Hillier states

"that in principle, spatial configuration can play a role in all three domains of sustainability: the environmental, the economic and the social" (Hillier, 2009, p. 18). He suggests that the cities shaped organically – meaning the cities whose spatial configuration is structured fluently through time and acknowledging the constant evolution of the city inhabitants' needs – do have a sustainable layout given their "micro- and macro-structure".

In more recent studies Akkelies van Nes and Daniela Santilli et. al. proved that certain spatial features increase or decrease the streets' walkability potential, which also improves the possibility of a city area being sustainable in terms of mobility.

Van Nes argues the way both micro and macro spatial conditions influence the walkability performance of an area especially in terms of safety, and how safety modifies people's walking behaviour – mostly women's. Furthermore, "a highly integrated street network on various scale levels is a sufficient condition for the location of economic activities. Likewise, a highly integrated street network with high angular choice values with both high and low metrical radii is a sufficient condition for high sustainable through-movement potentials in terms of high degrees of walkability" (Van Nes, 2021, p. 20). The term "urban compactness" framed by Van Nes implies that not only the space syntax high integration values help the performance of a walkability score, but also suggests that small blocks and the openness in buildings façades' towards the street add to a positive walkable environment and therefore a sustainable mobility pattern (Van Nes, 2021). Meaning that the spatial configuration of the SEZ's studied in this paper should also be related to other factors such as the segment length and the street permeability to add or reduce their sustainable performance within the street network. "Blind walls and buildings turned away from streets are perceived to be unsafe and enhance avoidance" (Van Nes, 2021, p. 20), thus what features are SEZ's bringing to their immediate urban context and how are these features performed towards a sustainable relation to the city?

2.6 Hypotheses and Conclusions

The implementation of SEZ policies in the GAM, and generally in Costa Rica, is considered a successful case in terms of economy, source of employment, social inclusion, and interaction with the local market. There is also evidence suggesting that the urban agglomeration performs poorly from the urban and sustainable perspective. The GAM seems to struggle to implement more sustainable ways of transport, and it can be implied that the current car-centric situation may weaken the overall performance of the GAM in terms of mobility and movement, and therefore, in terms of urban sustainability. Moreover, the literature reviewed mentions the importance of diverse land uses in close proximity to reduce the use of private cars and boost active mobility. It is understood that some SEZs in the GAM are large areas above 50 hectares, especially those in industrial parks. This suggests that most uses in a walkable distance may be predominantly industrial, encouraging the use of private cars to reach surrounding places of different nature due to the potential wide distances.

Despite the existing evidence of the poor urban mobility behaviour of the GAM due to its car-centrism, it is rather scarce the information specifically related with the SEZs role within the city. The analysis aims to understand if the spatial configuration surrounding the SEZs is more accessible by car or by foot. This helps us comprehend whether the accessibility of the network contributes to this car-oriented development and/or if it could help boost the spatial potential for more pedestrian movement. The following two hypotheses were proposed to help achieve the objectives of this paper:

1. SEZs are more accessible for vehicles than for pedestrians, given the relationship between the SEZs and the urban movement in the spatial network.
2. The land use of around 800m from the SEZs is predominantly industrial (monofunctional) or of scarce diversity.

In general, the literature reviewed showed insufficient information of SEZs' urban performance and their spatial aspects. This paper aims to open the discussion of SEZs and their role in cities to promote sustainable urban mobility from a Space Syntax approach.

3 DATASETS AND METHODS

First, a Normalised Angular Choice (NACH) distribution for vehicular and pedestrian movement was conducted to examine the accessibility patterns around the SEZs at different scales. Following, the section of Land Use Distribution explains the dominant land-use in the area and to what extent this has a relationship to the spatial distribution of each studied SEZs. Finally, the last section strengthens the land use distribution results through statistical analysis.

The following datasets were used to carry out these analyses:

(1) the spatial network of the GAM with a radius of 7km. (approx. 20 000 street segments).
(2) a dataset with location, name, services provided by SEZs registered in Costa Rica and located in the area of interest (Municipalidad de Heredia, Esri, HERE, Garmin, & USGS, n.d.)
(3) land use categorization in a 800m context of each SEZs using the open source Map data by Google (2015) ESRI Base map y OpenStreetMap (OpenStreetMap Foundation, 2004), opened in QGIS.

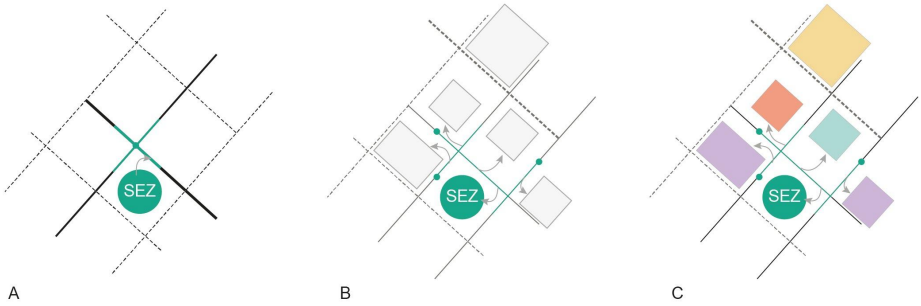

Figure 2: Methodology Summary: A. Accessibility patterns around the SEZs. B. The section of Land Use Distribution. C. Land use distribution through statistical analysis.

The main methods used for the analysis in this research were space syntax spatial analysis through Depthmap and QGIS. The spatial network was simplified from Open Street Maps using the Road Centre Line Simplification Principles for Angular Segment Analysis (Kolovou, et al., 2017).

The spatial network was then analysed through Depthmap, while QGIS was used to create the analysis maps. Moreover, the land use was added to the network analysis using QGIS tools. All the data was cleaned before analysing it to avoid inconsistencies in the results. The spatial analysis was initially performed looking for the measures of choice and integration at various scales, using the same model for both pedestrian and vehicular movement. Local and global measures of choice – radii 800m and 5000m – were chosen because they showed a realistic representation of the actual movement in the area and were further analysed along with the SEZ's location and their surrounding land use. This helped determine the potential pedestrian or vehicular flow around the SEZs and the relation these have or have not to their immediate urban context.

The Normalised Angular Choice (NACH) distribution for vehicular and pedestrian movement took into consideration the main street next to the entrance of each SEZa. These values were spatially joined with each SEZ and distribution percentages were calculated.

The area of study of each SEZs was delimited using the Catchment feature of the Space Syntax Toolkit (Space Syntax Laboratory and Space Syntax Limited, 2021). The land use data was mapped manually within the 800m of these catchment areas (see Figure 3). For this investigation, the analysed land use considers industrial, mixed, residential, and commercial land uses. The commercial activities are taken into consideration if they are directly connected to a street segment and if they can be reached by pedestrians on the ground floor. The dominant land use per each segment was calculated, instead of plot by plot.

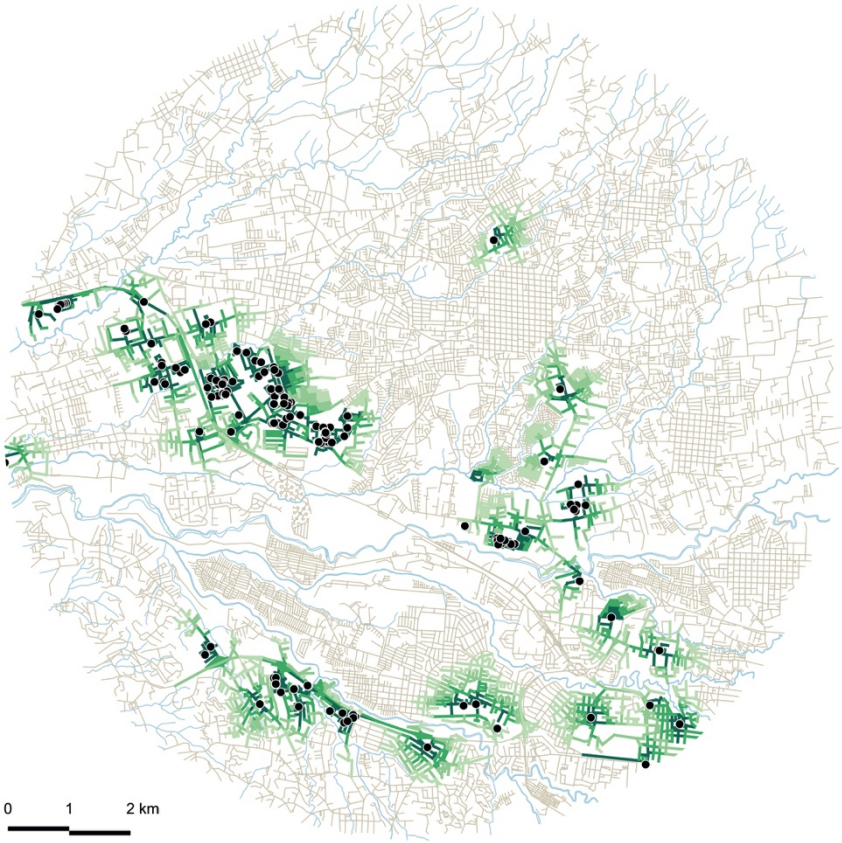

Figure 3: Catchment Analysis of 800 m. The points representing the location of SEZs were used as origins for the analysis.

The catchment area of 800 m from each of the SEZs helped identify a guideline to map the land uses around each of SEZs. Each segment of the spatial network map obtained from the Catchment analysis was directly related to one land use only – the predominant one. The land uses mapped were categorised in the following five land uses:

(1) Industrial Use: areas shown in purple. The segment was identified as industrial when the fronts were greater or equal to 66% industrial. This use included the SEZs themselves, as well as yet not limited to: manufacturing factories, storage warehouses, workplaces, office centres, among others of similar regard.
(2) Commercial Use: areas shown in red. The segment was identified as retail when the fronts were greater or equal to 66% retail. This included yet not limited to: retail such as shops, convenience stores, supermarkets, malls, open-to-public offices, restaurants, pubs, hair salons and barbers, workshops, among others of similar regard where a product or a service could be obtained by the public.

(3) Mixed Use: areas shown in teal. The segment was identified as mixed when the fronts were between 33% and 66% of at least two uses. This included yet not limited to a mix of industrial and retail, industrial and residential, and residential and retail.
(4) Residential Use: areas shown in yellow. The segment was identified as retail when the fronts were greater or equal to 66% residential. This included yet was not limited to detached and semi-detached houses, flats, among others regarding housing development. Public areas were included in this category, since according to the regulations of subdivision and urbanisation of the Instituto de Vivienda y Urbanismo (INVU, 2019) the public area ceased as residentials must be 5% -20% of the development area.
(5) Blank Frontages: areas shown in grey. The segment was identified as a blank frontage when the fronts were greater or equal to 66% lacking a use. This included yet not limited to: undeveloped or vacant lots, scrubland, large parking lots, large fences or walls with no entrance, among others of similar regard.

Additionally, the spatial values were added through a spatial join to all land use data points. The model then included the classification of the land use added to the spatial values of NACH which allowed us to study the urban performance of the SEZ in the GAM.

For testing the relationship between land use and accessibility, independent sample t-Tests were performed. These tests compare the mean accessibility of one land use group to another. For example, they compare the non-commercial group (commercial = 0) to the mean accessibility of the commercial group (commercial = 1) and calculates whether the difference is statistically significant. These tests were performed for each type of land use in both vehicular and pedestrian scales through JMP software.

4 RESULTS

4.1 Spatial Accessibility Study

The spatial accessibility study of the SEZs in the spatial network analysis radius is explained in this section. Space Syntax methods have shown that the geometry of the street network influences greater movement on more connected streets, and therefore land use distribution is influenced by the street accessibility as well. The theory of “movement economy” (Hillier & Penn, 1996) argues that the activities within a city or land use distribution is linked to the flow of movement within the street networks. This theory also explains how these activities or land uses are flexible and take advantage of the movement flow.

Table 1: Distribution of Normalised Angular Choice (NACH) values

NACH Values Range		NACH_r5000m	NACH_r800m
	1.4000 - 1.3571	5.74%	4.63%
	1.3570 - 1.2721	**20.44%**	21.21%
	1.2720 - 1.1861	13.80%	**23.58%**
	1.1860 - 1.1001	17.12%	16.47%
	1.1000 - 1.0151	19.96%	11.26%
	1.0150 - 0.9230	6.22%	7.00%
	0.9229 - 0.8431	10.48%	9.36%
	0.8430 - 0.0000	5.69%	6.52%

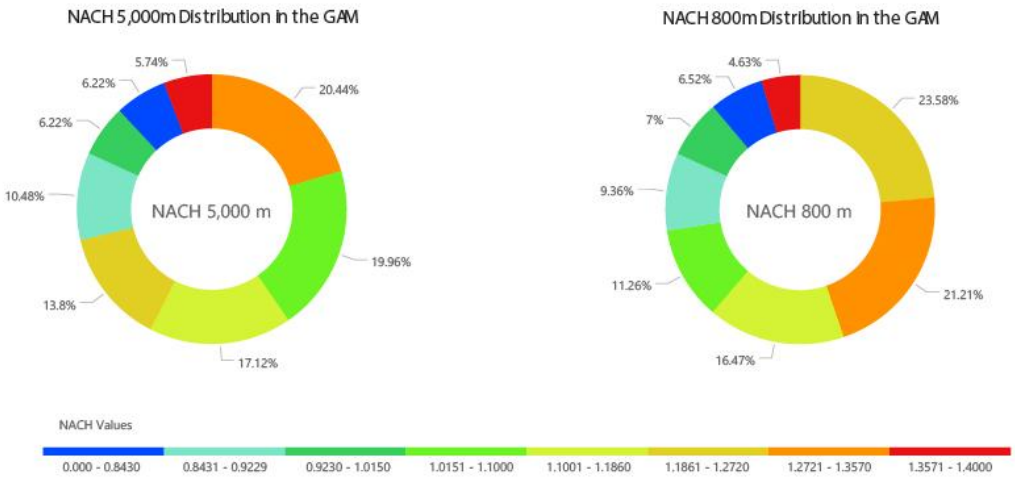

Figure 4: Graphic representation of the Distribution of Normalised Angular Choice (NACH) values

The maps in Figure 5 show the focal location of the SEZs in the periphery of Heredia and San José. The distribution of SEZs in the GAM is characterised by their proximity to the most connected highways in San Jose city as well as to the city airports located in the periphery. In the case of Costa Rican SEZs, there is a strong connection between spatial accessibility and the location of SEZs. SEZs are in close proximity to the most accessible highways and airports of the

city. Domestic and international goods transportation is manageable due to the strategic positioning of the SEZs within the urban fabric. This fact proves the SEZs economic success.

In order to understand how accessible the SEZs are, two scales of movement were analysed, the global (NACH radius 5000m) and the local (NACH radius 800m). These represented the walking distance of locals (10 minutes) and an average vehicular speed. Figure 5 on the top shows the global accessibility of the GAM context, and how they tend to be close but not exactly on the most accessible streets.

For having a deeper understanding of the SEZS distribution in the urban fabric, a breakdown of the NACH values of the street network studied was done. The results of this breakdown aimed to quantify the spatial accessibility of each SEZ is shown on Table 1 where each percentage of segments is categorised by the typical Space Syntax NACH ranges.

On a vehicular and pedestrian scale, the study shows that the predominant values of spatial accessibility are the second and third accessible range of values (1.3570-1.2721 & 1.2720-1.1861).

On a global scale (NACH r5000m) 20.44% of the segments belong to the second range of (1.3570-1.2721), whereas on a local scale (NACH r800m) 23.58% of the segment belong to the thirds range (1.2720-1.1861).

These results reflect that on average 22.01% of the street segments are highly accessible in both scales – which theoretically is defined as intelligible street segments (Hillier & Penn, 1996).

4.2 Land Use Distribution Study:

The following section explains the results of the land use distribution around the SEZs. The combination of the "movement economy" theory (Hillier & Penn, 1996) with a categorisation of the land uses around the SEZs, and the NACH values of the street network provided a deeper understanding of the allocation of the city's activities around the SEZs. Hillier and Penn (1996) explained the adaptability of the land uses or activities within cities according to the flow of movement in the street network.

The SEZs are embedded in Industrial Zones themselves (shown in purple on Figure 6), there is a provision of commercial areas (shown in red on Figure 6) towards the most accessible roads of these Industrial Zones, and a distribution of residential areas at the external and less accessible roads around the SEZs.

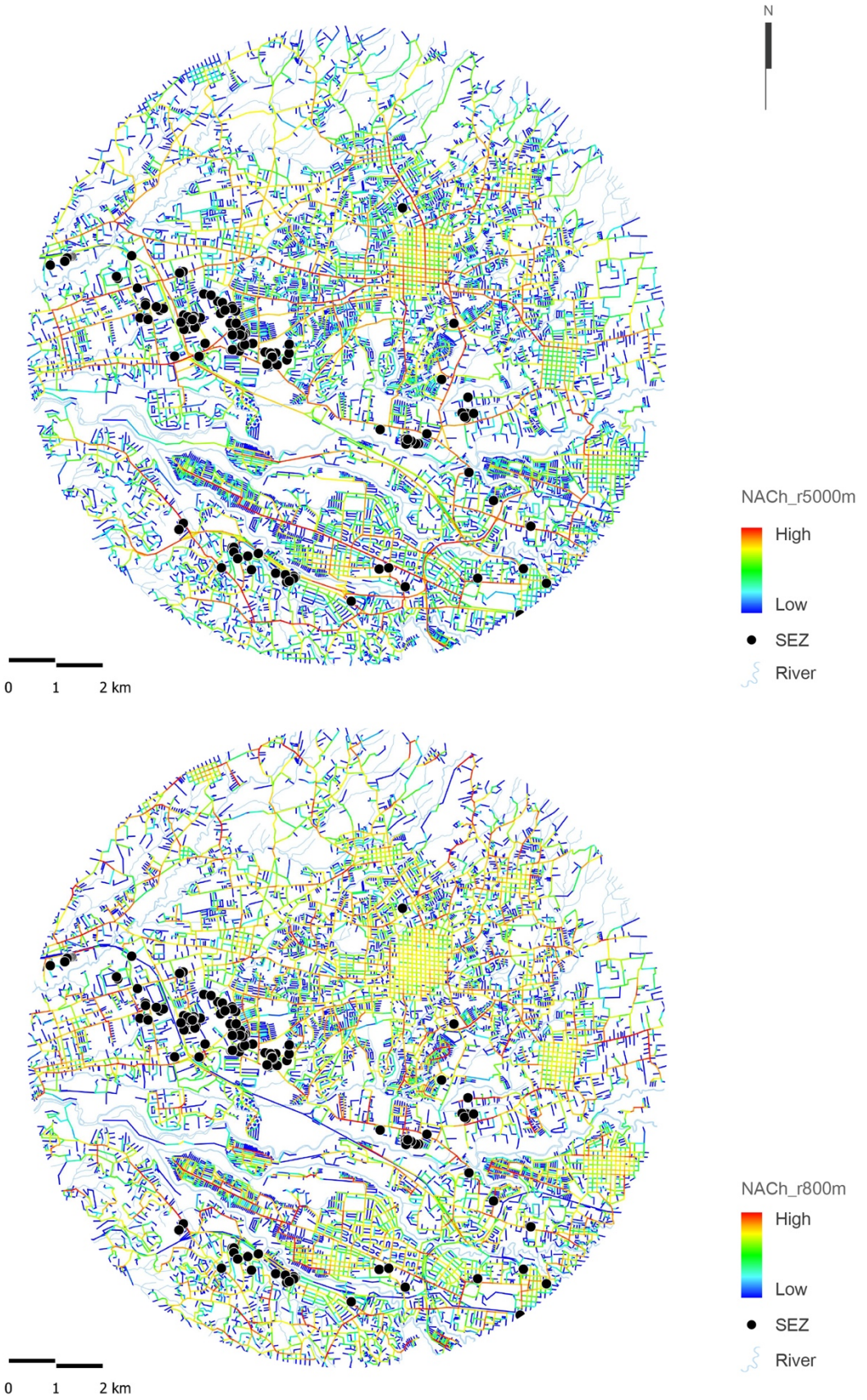

Figure 5: Normalised Angular Choice (NACH) radii maps (800m and 5000m) and the location of the SEZs studied.

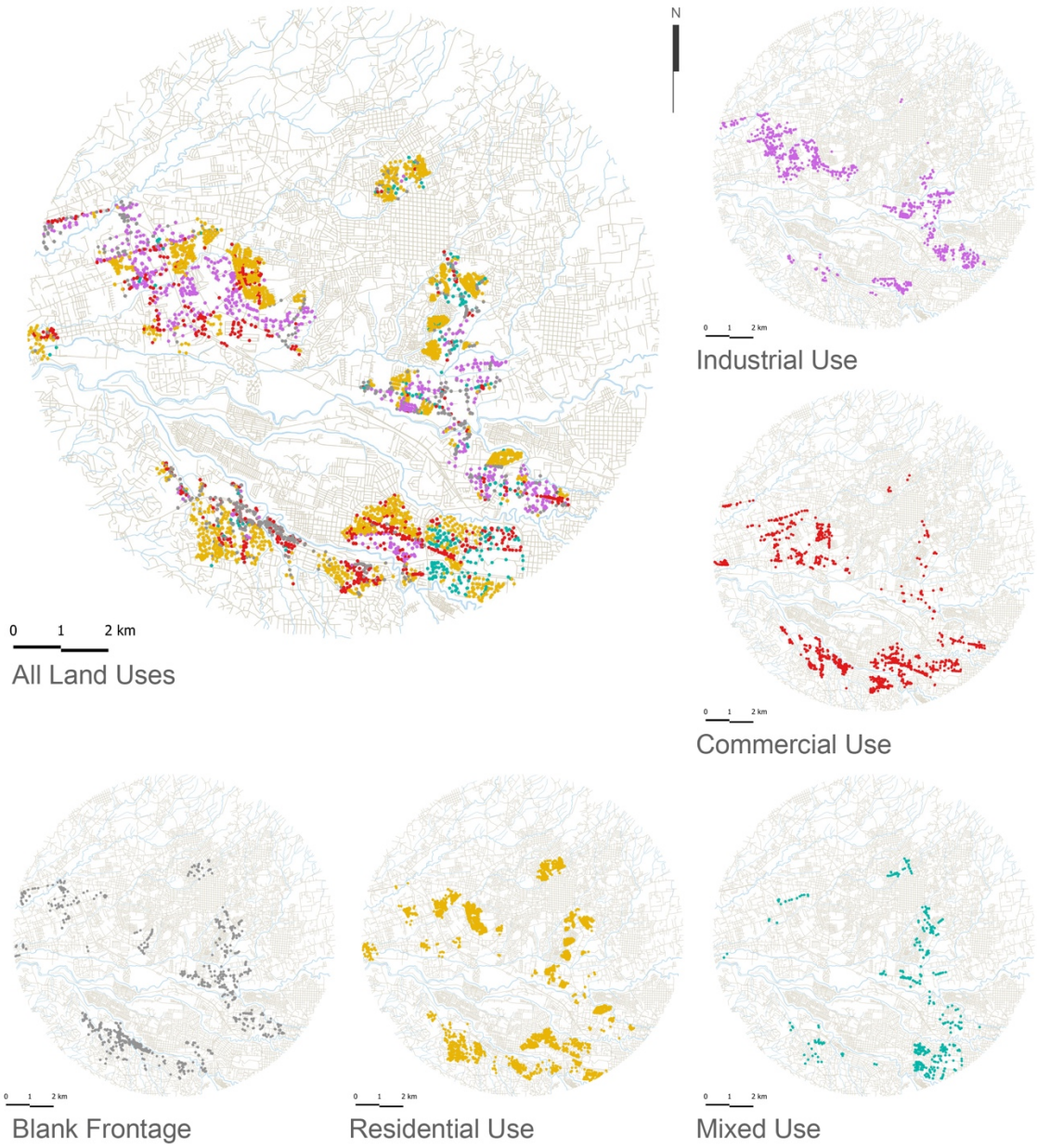

Figure 6: All land uses in 800m catchment of each SEZ and land uses studies patterns.

The land use distribution pattern around the SEZs in the GAM shows that more economically active land use types are associated with more accessible roads and that quieter and more private types of land use are associated with less accessible roads (residential areas) (see Figure 5 and Figure 6). Empirical studies show the relationship between street accessibility with the availability of commercial land uses (Omer & Goldblatt, 2016). Besides, in the studied area the mix use is highly accessible, whereas the industrial sites are mostly well integrated at their entrance, which many times are located on the high streets.

In conclusion, the general outcome from the land use mapping around the SEZs highlights the combination of an active typology of land use in close proximity to the main streets, a mixed-use and industrial land use on secondary roads, and quieter residential areas on the third level of deepness within the street network.

4.3 Land Use and Spatial Accessibility - Statistical Analysis

The results that show the relationship between land use and spatial accessibility are reported in this section. The results obtained from the t-Tests are also represented in box plots to help visualise the data and show the distribution of it in each category.

Industrial use

Industrial land uses have a different relationship with the street networks' accessibility. The independent sample t-Test of industrial uses, on a vehicular scale (Figure 7. A.), shows that the mean spatial accessibility of an industrial land use is slightly lower to the mean spatial accessibility of a non-industrial type, and this difference is statistically significant (t ratio of -4.7350, p value of <0.0001). On a local scale (Figure 7. B.), the t-Tests show that the mean spatial accessibility of an industrial land use is also lower than all non-industrial land uses (t ratio of -4.4109, p value of <0.0001).

Commercial use

The independent sample t-Test (Figure 7. E.) shows that the mean vehicular accessibility of a commercial type land use is greater than the mean vehicular accessibility of a non-commercial type one. This difference is statistically significant (t ratio of 10.2772, p value of <0.0001). Higher values of spatial accessibility have been associated with commercial frontages.

On a local scale, this relationship is repeated (Figure 7. F.). The mean pedestrian spatial accessibility (NACH radius 800m) of a commercial type land use is greater than the mean pedestrian accessibility of a non-commercial type land use, and this difference is statistically significant too (t ratio of 8.1625, p value of <0.0001). In other words, commercial land uses tend to have higher spatial accessibility in both vehicular and pedestrian movements.

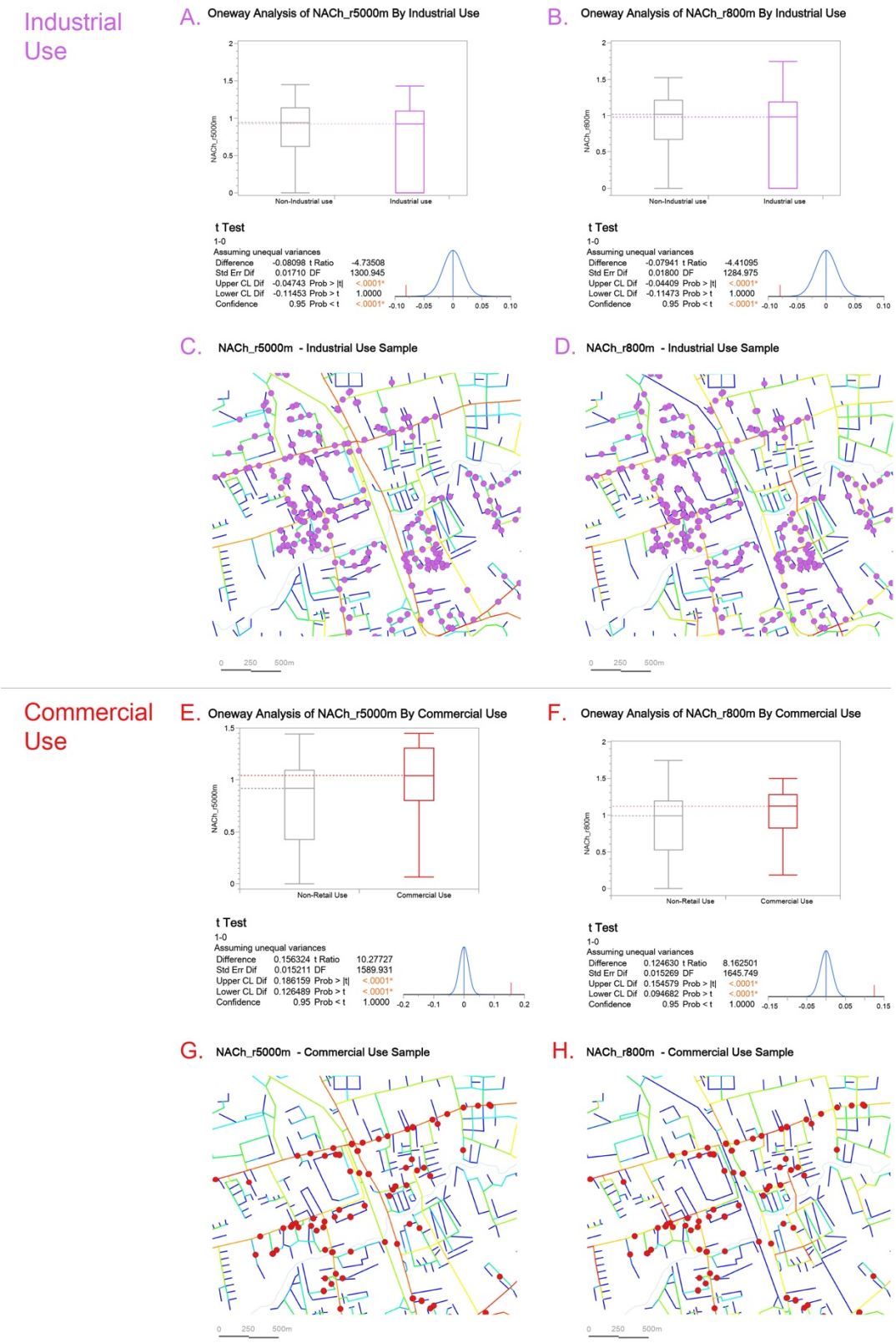

Figure 7: One way analysis t-Tests of Industrial and Commercial Use for vehicular and pedestrian accessibility. Below, sample close-ups of the network studied with the respective land uses.

Mixed use

Mixed land uses have a similar relationship with the street networks' accessibility as commercial land uses have. The independent sample t-Test of mixed land uses, on a vehicular or global scale (Figure 8. I.), shows that its mean spatial accessibility is higher to the mean spatial accessibility of a non-mixed use land type, and its difference is statistically significant too (t ratio of 5.2154, p value of <0.0001). On a walkable scale of 800m (Figure 8. J.), the test shows that the mean spatial accessibility of a mixed land use is also higher than all no-mixed land uses, also statistically significant (t ratio of 3.9636, p value of <0.0001).

Residential use

Residential land uses tend to be found on streets with low accessibility or segregated streets. As expected, the independent sample t-Test of residential land uses – on a global scale (Figure 8. M.) – shows that its mean spatial accessibility is lower than the mean spatial accessibility of a non-residential land type. This difference is statistically significant (t ratio of -8.9411, p value of <0.0001).

Moreover, the t-Test (Figure 8. N.) shows that the mean spatial accessibility of a residential land use on a scale of 800m is also lower than all non-residential land uses; such difference is statistically significant as well (t ratio of -4.2977, p value of <0.0001). Both tests confirm that residential land uses tend to be located on less accessible streets, locally and globally.

Blank frontages

Black frontages or void land uses have a peculiar relationship with accessibility. The tests show on a global scale that the mean vehicular accessibility of a blank frontage type is slightly higher than the mean vehicular accessibility of all others land uses. This difference is statistically significant (t ratio of 3,0179, p value of <0.0026). Main roads that are high in spatially accessibility, tend to have blank frontages which can explain this relationship.

The t-Test shows that the mean spatial accessibility of a blank frontage on a local scale is slightly lower than all non-blank frontages, which difference is not statistically significant (t ratio of -0.1786, p value of <0.8583).

In summary, the tests that explain the relationship between land use and spatial accessibility have shown that each type of land use, except blank frontages, are explained by their accessibility. More active land uses like commercial and mixed use have a significant difference with its spatial accessibility on non-commercial and non-mixed ones. Whereas non-active land uses like industrial and residential do the opposite, they tend to have lower accessibility than non-industrial and non-residential areas.

Figure 8: One way analysis t-Tests of Mixed and Residential land use for vehicular and pedestrian accessibility. Below, sample close-ups of the network studied with the respective land uses.

5 CONCLUSIONS

The development and evolution of SEZs in Costa Rica is particular. They change as the economy progresses in the country, and this can be seen throughout this research. The SEZs are successful because they evolve with the economy and the movement generated (FIAS, 2008). They are embedded in the urban fabric and depending on the economical context, they change accordingly. Their adaptability is a characteristic that can be categorised as sustainable with its urban context.

The aim of this paper was to comprehend if SEZs in Costa Rica promotes sustainable urban mobility the way they promote economic and social growth. The hypothesis of this research paper was that SEZs were performing poorly from a sustainable mobility perspective since their configuration tends to set a wall to its context. It was perceived as car-oriented rather than pedestrian friendly and seemed to lack land use diversity around them. This hypothesis is rejected since the results of this research shows that, in a general, SEZs are highly accessible for both motorised vehicles and pedestrians, which supports the argument that they are indeed sustainable towards their immediate urban context. Furthermore, the land use surrounding the SEZs within an 800m catchment is not monofunctional – meaning that there is a variety of land uses according to the city's spatial network distribution (four or five land use types were counted per SEZ).

"Economic zone programs that are successful in contributing to long-term development go beyond the static benefits of attracting investment and generating employment. They leverage these static benefits for the creation of *dynamic economic benefits*. Ultimately, this means contributing to structural transformation of the economy, including diversification, upgrades, and increased openness" (Farole & Akinci, 2011, p. 13). The SEZs located in the GAM apparently do fulfil this purpose, at least regarding their spatial location within the urban fabric.

Empirical research has suggested that in countries with populations of less than 5 million people SEZ are more likely to become a "significant source of employment" (FIAS, 2008, p. 35). Due to Costa Rica's scale, this might be one important reason why SEZs in this country have been thus so far successful. Therefore, in the aim to continue developing successful SEZs within the known parameters, this research proposes that they are embedded in their surroundings (globally and locally) and address global new trends in low-carbon and green growth, among others.

The results of the investigation show that the distribution of SEZs in the GAM is characterised by their proximity to the most connected highways in the city as well as to the highly accessible streets in the neighbourhoods where they are located, in order to rapidly access main roads that connect to airports, ports and other distribution centres. The Land Use Distribution Analysis shows that dominant land-uses in the areas close to each studied SEZs are distributed logically according to the movement economy of each SEZ: more movement-based activities like retail and mixed use tend to be in the highly accessible streets and vehicular oriented ones, whereas

less movement-based land uses are found in more segregated streets. Finally, it was statistically proven that there is a strong relationship between spatial accessibility and land use type, they are statistically significant in all types (both globally and locally), except for local spatial accessibility in blank frontages.

Apart from the acknowledged success of SEZs in reducing unemployment, promoting exports and boosting the local economy, among others (Monge-González, et al., 2005), existing literature leaves aside their spatial performance and the relationship with their context. The scarce spatial theories about this topic were a definitive motive to undertake this investigation and to continue learning about this topic.

The next steps of this research will be to categorise and understand the different typologies of SEZs that develop in Costa Rica, these typologies will be mapped and studied with more detail, including on-site observation and statistical tests. Moreover, to understand their spatial layout and connection to their context. Understand how each type is embedded in the urban fabric and how well integrated they are. The mapping of land uses will be quantified and statistical analysis will follow, in order to understand what patterns land use and value tends to have in these environments. This research will continue with a Multivariate Model that takes into consideration public transportation and green areas.

The most important methodological achievement based on this research will be an Urban Sustainability Tool that will allow stakeholders to test how sustainable their local SEZs are not only from a mobility perspective. This tool is thought to be designed to measure different variables to determine the sustainable performance a SEZ has, not only for Costa Rica, but for SEZ all over the world. It will enable people to think and rethink – if necessary – the impact SEZs have over their immediate urban and social context.

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