

URBAN ROADS AND SOCIAL METABOLISM: A SUSTAINABLE DEVELOPMENT STRATEGY FOR SAN JUAN, PUERTO RICO

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ABSTRACT

The present work explores the relationship between an urban road with both, socio-metabolic processes and natural systems patterns. The premise is that roads have a decisive impact on energy, material flows and connectivity between biological structures. Therefore, urban metabolism - Social and natural processes measured out of energy use, material flows and land use - becomes the appropriate instrument to assess and analyze the functionality of the different components operating in artificial and natural systems. The case study traces the metabolic behaviors that result from the cross of Juan Ponce de León Avenue through the water system composed by the estuary of Martín Peña and Río Piedras River. A theoretical framework based on social equity, economy, and ecology is being applied in data collection and analysis. Parametric methodologies and GIS information are used to describe the structural and functional properties of both natural and urban systems. The collected data enable the understanding that the simultaneous loss of energy efficiency and land-use efficiency from the mid-20th century to the present affects the resilience of the area. Consequently, this exploration demonstrates the importance of urban metabolism in maintaining the ecological quality of natural systems. As a result, it proposes an urban metabolism strategy to develop more sustainable urban schemes for the systems composed of urban roads and natural ecosystems. The organized complexity of the water system, necessary to host biodiversity and fundamental ecological processes, cannot be guaranteed if the urban metabolism is not taken into account.

Keywords: urban metabolism, urban roads, resilience, urban sustainability.

1 INTRODUCTION

The cultural landscapes have been imprinting its traces on a palimpsest that reminiscent of different times in which human activity has shaped the environment. In this palimpsest, the streets have left their indelible mark. The problem that concerns this work lies in the purpose of these traces. Accordingly, with the fundamental aim of connecting and facilitating displacement, other functions of the street linked to natural and social processes occurring in the city should be recognized. In this sense, are developed four key themes. The first theme is presented a historical view of the street, highlighting its role in the urban metabolism. The second theme addresses the change in the relationship between street and urban metabolism from the industrial revolution due to the creation of new materials, the intensity of vehicular use and the growth of the city. The third theme sketches the importance of the vehicular routes in the model of urban development of San Juan, a pattern that can be recognized similar in different Latin American cities and the industrialized world in general. The fourth theme presents the case study and finally is presented a proposal that exposes the opportunities of the street to become a concatenator of the metabolic processes in a case study: Juan Ponce de León Avenue in the city of San Juan in Puerto Rico.

2 STREETS AND URBAN METABOLISM

The urban metabolism has its origin in recognition of the limits that impose the natural and social resources to the industrial models of making the city. Fisher-Kowalski [1], defines it



as a process composed of biophysical inputs and outputs summarized in the materials and energy that are extracted from the environment and are treated (ingested) by society. Some of these materials are accumulated as a socioeconomic stock while another part is thrown into the environment in the form of waste or polluting emissions. Beyond the accounting of raw materials, manufacturing, waste, and energy, urban metabolism should understand as a social practice. Therefore, there is a visible and quantifiable part that manifested in material and energy flows beside an immaterial part determined by the institutions and the ensuing symbolic and social systems. Both parts, material and immaterial, determine each other [2]. Thus, each society shapes its urban metabolism regarding the relationships establishes with its environment.

Organic-based pre-industrial cities teach that the street was an essential part of the urban metabolism configuration. So, the artificial basins defined by the layout of the streets concerning the system of fountains and channels work as an orchestrated machinery that contributed to feeding the orchards of the urban periphery.

Fig. 1 below shows an orchard feeding a pond that collects runoff water from areas of higher elevation in Brañas del Sar, Santiago de Compostela. Next, to this image, Fig. 2 shows the layout of the Castillo del Morro's floor, its configuration reflects the intended gesture of water collection, integrating aesthetics and functions values.

The hydrological system determined for a long time the scheme for spatial organization of houses, cultivation areas, morphology, and plot of streets, in general terms, the relationship between the city and its surroundings. The preponderance of water in the design of the city is why this has always been the most quantitatively significant flow of those circulate through its metabolism. Consequently, the street, in the pre-industrial city, the concatenator. It was not, as at present, strictly a means of displacement.

The slopes were oriented to lead the runoff to the orchards in the agricultural fields that bordered the city and fed with the fertility of the organic material carried by the water and deposited there. The level of permeability modified with the intention that was having concerning the water. Thus, the street worked, in some cases, as a channel, to lead the water toward the orchards or cisterns, in other cases worked as a permeable surface that by absorption allowed the reduction of the runoff. The street was part of an articulated urban design and natural processes; on the one hand, its benefits were taken advantage of, such as irrigation and water storage, and on the other, phenomena such as torrential rains were reduced. For organically based societies - those that still survive -, the primary resources for its subsistence come from a biosphere management that must ensure maintenance and



Figure 1: Water Management. Brañas del Sar Santiago de Compestela.



Figure 2: Layout of Castillo del Morro's floor. San Juan, Puerto Rico.

reproduction. The balance in relationships to the environment not only allows the meeting needs but also represent a guarantee of survival. These societies depend on its surroundings, so, the closure of metabolic cycles should be a condition.

Therefore, the lessons of these societies, allow us to recognize that is important to recover some kindness of the street. This reading can contribute to responding to the challenges of the present city and advanced towards sustainable future.

3 THE DEVELOPMENT PROCESS OF THE CITY LINKED TO THE STREETS AND THE IMPACTS ON URBAN METABOLISM

For pre-industrial or organic-based society, the resource management was the basis of its survival, more not for industrial-based society, which can become independent of the fertility of its soils because the resources are obtained from distant lands. The discovery of new ways of achieving energy on a larger scale has generated great changes in the relationship between human habitat and natural processes. Industrial system has progressed in a type of knowledge and technology appropriate to a society independent of the organic basis. The new model considered energy and material flow as inputs and not as part of processes that require a continuous regeneration. This unlinking between natural and social processes was possible because of the accessibility to fossil fuels as energy, a source capable of providing work and energy.

Organic technical systems must have nutrient recycling strategies, the closure of material cycles and the waste returns to the environment to ensure future resources. Nothing similar occurs to an industrial system: the availability of the resource in the mines does not depend on the return to waste to it. On the contrary, waste is a nuisance that distorts the efficiency of the industrial system, therefore should be removed as soon as possible. The productive value of the waste was shattered with linear metabolism, in which the materials are extracted from the earth's crust, are transformed into usefulness products by the industrial processes to meet social needs, are consumed, and, consequently, degraded and discharged into the environment. So, this mineral-based industrial technical system is a waste production system. As a result, has led a cut with natural processes that cause the deterioration of the environment that supports life on earth.

This linear metabolism that characterizes the current urban model has transformed the landscape faster than any other process of any another time of history. New materials allowed the rapid infrastructures construction. The asphalt enables the extension of the road network by all the confine, and with this, increase the use of private vehicle use, access to a significant percentage of the population.

Linear metabolism also made it possible to create new types of roads other than the street. The change in the intensity of vehicular use resulted in new needs for faster movement, which were covered by the expressway, in which the relationship between persons and environment changed completely. The fragment produced by these roads to the landscape is very evident. However, it is not the only fragment, these roads also affect the sociocultural level, as ancestral customs. There were a lot of ancient grazing routes, linked to a cultural landscape, that has been modified or eliminated.

Something different happens to the arteries or main streets of the city, defined as those that connect and distribute the vehicles between the various areas. These roads allow a different relationship between the public space, the urban elements, and the pedestrian. The main street gives entry to the city and connects with the secondary streets. Goes through commercial, cultural, and institutional areas, and leads to public spaces. The speed of its routes allows the driver to observe the buildings and its urban identity elements, and form a sketched of the city, unlike the expressway, which, even if it passes through the downtown, does not allow its recognition.

These qualities of the main street are an opportunity to make use of the unifying potential given by its functional pre-eminence and relationship with the city and concatenate it with the processes of urban metabolism. The main street, currently covered by waterproof tarmac and a usually collapsed sewerage system, could resume the channeling role of the metabolic flows and make them visible.

The visibility of natural processes, such as the cycles of water and raw materials, contributes to generating links between people and the natural environment. This links translates into practice pointed to maintaining and preserving the health and the the environmental productivity.

4 BRIEF HISTORICAL REVIEW OF THE URBAN DEVELOPMENT OF THE CITY OF SAN JUAN AND ITS ROAD SYSTEM

An analysis of San Juan urban development is fundamental to understand the relevance to its road system in relationship to the city model. The low density and the dispersed pattern of the residential areas stand out as a relevant feature. The pre-eminence of the metropolitan area, where more than half of the population of the island lives, have most of the services concentrated.

However, this was not always the case. Initially, the inhabitants of San Juan settled on the islet, whose strategic location motivated the construction of walls, fortresses, and the establishment of administrative headquarters.

It could be recognized significant reminiscences of an urban design linked to natural processes in Old San Juan. Even though cisterns are currently in disuse, there are a lot with different capacities. The antic houses collected the water through the roofs and canals of the central patios. Larger buildings such as the castles El Morro and San Cristóbal, or the barracks of Ballajá, also integrated into its design and configuration the management of this vital resource. Their patios through its impervious surfaces, slope orientation, and channel systems led the water toward huge cisterns. According to the United States Department of National Parks, the cisterns of the two castles could hold nearly one million



gallons of water, about half of the annual rainfall of San Juan. This amount of water being able to supply all San Juan in the case of drought [3]. The cobbled street of Old City allows permeability and contribute to reducing the runoff. All these considerations related to the natural processes were lost with the rapid growth linked to industrialization.

At the end of the 19th century, the city began to move outside the walls. Overpopulation caused wealthy families who had summer houses in different areas such as Miramar or Condado to settle there. Another important factor of urban expansion was the tramway, which facilitated the tour of the whole island and formed a circuit that led to an urban growth linked to its route, which also connects with other cities developed in the 18th century, such as Rio Piedras and Bayamón. Fig. 3 below shows the railway circuit of the Island, which corresponds to the occupation of the territory shown in Fig. 4.



Figure 3: Railway circuit of the Island. (Source: Rodney, 1925.)

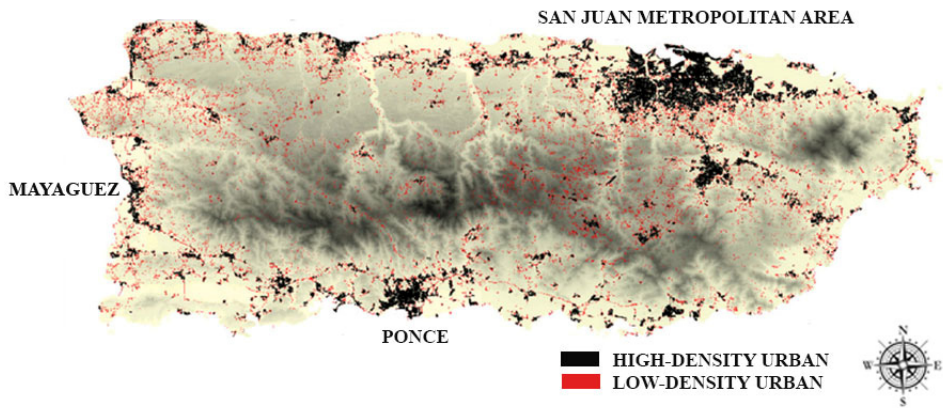


Figure 4: Development Pattern of Puerto Rico: High density (Black) and Low density (Red). (Source: Martinuzzi, Gould and Ramos, 2007.)



These road networks facilitated that San Juan grew from poles with different functions. These poles are the north-south axis formed by the sectors of Old San Juan, Santurce, Hato Rey and Río Piedras; The urban center of Bayamón; The cities of Carolina, Guaynabo, and Trujillo Alto [6]. This growth of nuclei modified its pattern of the 1940s when the island incorporated the dispersed model of the United States, which promoted the suburb linked to a green image concerning nature, contrary to the reality due to the long occupation of the soil [7]. In the 1950s and 1960s, a sense of economic prosperity generated fostered foreign investment. The population has risen sharply from the 1970s. This growth slowed, in 2000 to start a downward trend, which is still declining [1].

The car played a significant role in the urban development process. In 1930 the population moved into collective transport. Accordingly, the private vehicle was limited to the families of high income. In 2015, registered 661 motor vehicles per 1000 people. [8] This statistics places Puerto Rico in one of the countries with the highest number of vehicles per person. The environmental consequences of the excessive car use are evident in various senses: CO2 emissions, social inequity, economic impact, and a decrease in urban environmental quality.

As in the rest of the Latin American countries, Puerto Rico adopted not only the dispersed urban model but also the American way of life, which promotes an idea of development linked to the high consumption and relaxed lifestyle that promises, among other things, the car. With the car as the primary means of transport, urban sprawl has no physical limits. However, the residential areas isolated from urban centers, but dependent on its dynamics impoverish the quality of life of its inhabitants, who do not enjoy the best of the countryside because its landscape has been modified by moving away from the crops and greenery.

The population shift from central urban areas into suburbs, characteristic of western cities motivated by the promise of a substantial increase in income and quality of life. San Juan suffered the same process, but with the difference that many of the poor who moved to the periphery remained poor. The urban planning of the island in general, and of the metropolitan area, is characterized by cities and towns surrounded by dispersing urban expansion [5].

This urban model led to the construction of an extensive road network that responds almost exclusively to car journeys. In the metropolitan area, the short stretches with bike-lanes are recent, and the pedestrianization is difficult due to the disconnection of the sidewalk, the lack of shade, and unsafely crossings.

The road system of San Juan, not only does not respond to the pedestrian, but it also does not answer to the natural processes that inevitably affect the city. From its relationship to the water, the San Juan road system can be read as a waterproof tissue that covers the pavement from the highest to the lowest of the faint topography areas. This tissue alters the runoff and increases the risk of flooding. Consequently, the streets are overflowing, and, in some cases, buildings are affected. The most vulnerable areas are near the sea, lakes, and rivers, but there are also other sectors of the city affected due not to have adequate drainage. This situation could be different to a route planning relating to the qualities of climate, soil, and topography.

This situation is because the street is conceived only as a connector that must provide a surface of displacement for the car, not as an urban element that can canalize social and natural processes, through which could flow and be in a harmonious way circumstances that in the present collide and hinder.

5 CASE STUDY

Juan Ponce de León Avenue has features of urban archetype: The great street marked by the signs of a history that glorify its trace and that connects multiple sectors of the city, such as



Alcalá Street in Madrid, The Seventh of Bogotá, or the Avenue of the Insurgents in México City.

Juan Ponce de León Avenue was drawn in a rudimentary way before the Spanish Conquest, then it was widened during the colonization and was called “Central Road”, is the main connector of the capital with the Island. For centuries circulated by this way people and goods that served as support for the development of the capital and the country regarded as the backbone of the city. As a dirt road to the 16th century, it has been subject to several transformations. Known as Avenida Juan Ponce de Leon in the year 1913.

This Avenue covering a total of 11.49 kilometers longed to begin in the Plaza Colón in Old San Juan as a continuation of the Fortaleza Street, the main artery of the islet. Runs northeastern - southeast through the Santurce neighborhood, which includes differentiated urban areas. Portions of the road pass-through business, financial, and commercial district of Hato Rey called Golden Mile and ended in the district of Río Piedras, functional focus where there is the most important University Campus of the country. Predominate in this avenue institutional, cultural, educational, emblematic, and commercial buildings, as well as cultural activities and community and training centers. Highlights its pass over two natural water systems that are Martín Peña Channel and Río Piedras, estuaries of high ecological value. The junction with these natural systems, as well as the crossing with important streets, represent a potential to configure a broader system, in which this avenue would have a role that could respond to aimed for a more circular urban metabolism.

This approaching is related to a growing concern for the protection of diversity has given rise in Puerto Rico to consideration of the most effective means for maintaining and improving biological habitat.

Currently, Juan Ponce de León Avenue and the City of San Juan in general, are characterized by linear metabolism that expresses on impervious pavements, a sewer system that generate pollution and impact on water quality of local water bodies, and lack of waste management.

There is a disconnection between the inhabitants and the natural processes that increase due to the lack of public spaces, which are important to promote the community involvement with the environment. San Juan presents a variety of squares, parks and public spaces, the problem is that they are far away from the activity centers. To this adds up problems that affect the continuity, image, and security of the avenue, such as deteriorated buildings or underutilized spaces along the way, which difficult its perception as public space. The intrinsic qualities of this Avenue cry out to come to light, the goal of this work is to its rescue and honour.

6 PROPOSAL

Based on the recognition of the potential of the Juan Ponce de León Avenue, is proposed an urban metabolism transformation strategy for the city of San Juan. What is seeking is to reclaim the role that had once this great street, but raising the challenge to the current sustainable demand from its main scopes, namely, social, environmental, and economic. Below are explained the proposal foundations.

Social field: In the public space is constructed the idea of the city, is a place where can be measured out encounter, tolerance, citizenship performance and urban environmental quality. How to pose (Borja and Muxi [9]), is one in which the society becomes visible. Is associative and relational, facilitates the integration and participation. This proposal aims at setting up this avenue as a backbone and seeks in this regard prioritize the pedestrianization to increase its usefulness as a social space. As well as articulate and give continuity to squares, parks,



commercial, cultural, and service areas. This network of public spaces would favor the appropriation, understood as a sense of belonging. The conception of the urban space in these terms, does not arise only from the “places” but of the relationships between people, with which, citing Smith [10], are shared memory, values, symbols, myths, and traditions. The rescue of the heritage value of this avenue could contribute to the development of the history of the present. As Augé [11] acquaint, a re-reading in which are told the transformations that led to the current reality, and that contributes to face the challenges of the future.

It is well known the deterioration of many sectors of Juan Ponce de León Avenue by vandalism, a situation that could compare with the psycho-social experiment of the broken windows, the message which is being transmitted is: here nobody cares about this, this is abandoned. Contrary to this, if the public space is well taken care of and contributes to the increase of the quality of life, are built ties. In the words of Vidal and Pol [12], the appropriation facilitates environmentally responsible behaviours, as well as involvement and participation. Therefore, increase the experience of public space along the avenue is essential to achieve the sense of ownership and cooperation in its improvement and maintenance, these being the fundamental objectives of this proposal.

Environmental field: according to the Council of Climatic Changes in Puerto Rico [13], almost 90% of the work-related travel is made in private vehicle, which generates a high amount of emissions of greenhouse gases. Incorporate sustainable mobility - like bicycle and pedestrian lanes - to Juan Ponce de León Avenue could decrease the emissions produced by cars, considering that this avenue connects a large part of the institutions that are sources of employment.

However, this theme should be understood far beyond its landscape value or its contributions to environmental quality. This paper proposes that this avenue will configure as a large articulating machinery of urban metabolic processes. For this, it is necessary the reconfiguration of the street in two main senses: As a debugger capable of absorbing CO₂ through the greening of its paths, and as manager of the runoff through its collection, driving, and filtering. Because of these functions would result in the reduction of urban situations as water logging, or heat islands, which affect the city and increase the impact of natural phenomena. The integration of The Martin Peña Channel and Rio Piedra's River ecosystems would give continuity to the biophysical matrix that has been fragmented with the paving. This strategy would allow the recovery of biodiversity, as well as scenic and environmental qualities. Opportunities that also would achieve with this system are the incorporation of other sustainable practices such an integrated sustainable mobility circuit between the estuaries and the Avenue, waste separation, and the integration of renewable energy and environmental education. All these practices are fundamentals to achieve the primary objectives of urban sustainability.

Economic field: Revaluation of public space that would provide the system formed by Juan Ponce de León Avenue and its possible transverse axes would encourage investment and employment opportunities, which would result in economic prosperity. This avenue runs through areas of tourist value that are interrupted by broad depressed areas. The proposal of this urban corridor system would help to retrieve the value of the soil along its entire length. Recognizing the tourism as one of the primary economic sources of the island it can be identified that this proposal could contribute to increasing this potential. Participation of the community is considered fundamental to avoid the possible gentrification that tends to occur with these urban improvement processes.

To be able to recognize the criteria on which guide the study of the Juan Ponce de León Avenue and its possible configuration as the backbone of the urban metabolism, its proposed

a methodology aims at discovering and working with characteristics of a given locale. These features include the basics outlined above.

1. Spatial Criteria: Characterize the physical qualities of the place. Includes four specific topics:

- a) Intrinsic qualities: Recognizes characteristics of the site regarding morphology, geography, and other uses that allow defining best uses for some types of activities depending on the conditions of the street, such as tree planting, urban gardens, bike-lanes, others. As McHarg [14] proposed this ecological approach sees design as an iterative process that is largely shaped by the interactions between humans and ecosystems.
- b) Articulation: Identifies opportunities to set up organizational structures such as axes, nodes, and edges through the definition of possible spatial sequences, as well as environments with high functional dynamics that can concatenate the social and natural processes.
- c) Confluence: Explores and defines spaces for the meeting, which may already be configured or not. The Avenue and the system that integrated is supposed to facilitate the identification of new areas of social interaction.
- d) Management of metabolic fluxes: Examines the potential for acting in the transformation of the urban metabolism from its fluxes, mainly of the energy used for transport, the raw materials, and water. The reconfiguration of the metabolism fluxes is possible from the social action, from the citizen, without the need for high technologies nor very complex processes. So, the water, for example, given its strong presence in the city, in its streets and public spaces, could, through appropriate management, transport raw materials and fertility to the soil and no contamination, as is currently the case. This water management, as a concatenator flow of many of the processes of urban metabolism, facilitates the action on other metabolic fluxes. Therefore, it is necessary to carry out a map of metabolic fluxes to identify its behaviour. In the case of water, it would reconnect its channels and give continuity to hydraulic spaces. The streets are important because they inevitably are configured as artificial basins that lead the water flows by gravity to the natural water courses, and with this fluid, the material of runoff.
- e) Symbolic Criteria: Define referential places from the recognition of spaces that exemplify the city and represent it in the collective imagination. The importance of these areas for the reconfiguration of the urban metabolism lies in its social value, which could be achieved by the participation and involvement of the people with the places from which they feel are part and with which they form a sense of identity [15].

These criteria, as well as the research of parametric and GIS information used to describe the structural and functional properties of the study area, were considered to propose an Urban Metabolic Corridors System, defined as an organizational structure oriented to canalizing the natural and social processes in urban space. In which the streets would serve as corridors. Consequently, it is proposed a guideline oriented to:

- a. Describe the priorities and principles that will ensure future development achieves high design quality and design excellence.
- b. Improve habitat connectivity across the System, particularly between priority sites, and between identified habitat areas in adjoining natural ecosystems Caño de Martín Peña and Río Piedras.



- c. Increase the quality of urban life measured out from a substantially decrease a city's transport emissions and congestion through reduced car ownership and car mileage.
- d. Protect heritage items, heritage conservation areas and other highly valued characteristics across the System.
- e. Relate the street to the public space and to the empty spaces to encourage and support biodiversity.
- f. Reflect historical and cultural context.
- g. Encourage public transport use, walking and cycling.

The main themes of the guideline proposed are:

- Turn Juan Ponce de Leon Avenue into a main ecological corridor and generate transverse connectors that allow expanding the network of bike-lines and pedestrian pathways through integrated circuits to achieve a simple approach that aims to connect the social, economic and cultural life of the city to these means of transport.
- Nodes with amenities as water fountains, public toilets, public telephones, garbage bins, ATMs, street vendors and street entertainers at crossing points between the main and transverse axes, related to buildings or relevant urban spaces.
- Green Gateways to connect the hydrological ecosystems Caño de Martín Peña and Río Piedras, this would be allowing for efficient circulation systems (streets, metros, bus lanes, cycling paths, walk paths), attracting uses and activities, thus enhancing safety, providing opportunities for recreation, thus improving general good health and well-being. Gateways would facilitate citizen participation and engagement in the conception, production and/or subsequent maintenance of the space.
- Detailed analysis of the heritage items and conservation areas located within the Frame Areas along the System. As well as the unfunctional spaces and their opportunities of adaptive integration.
- Identifying the key elements of the existing built form which are significant from a heritage perspective, including consideration of the character and fine grain, and innovative ways to celebrate heritage along the System.

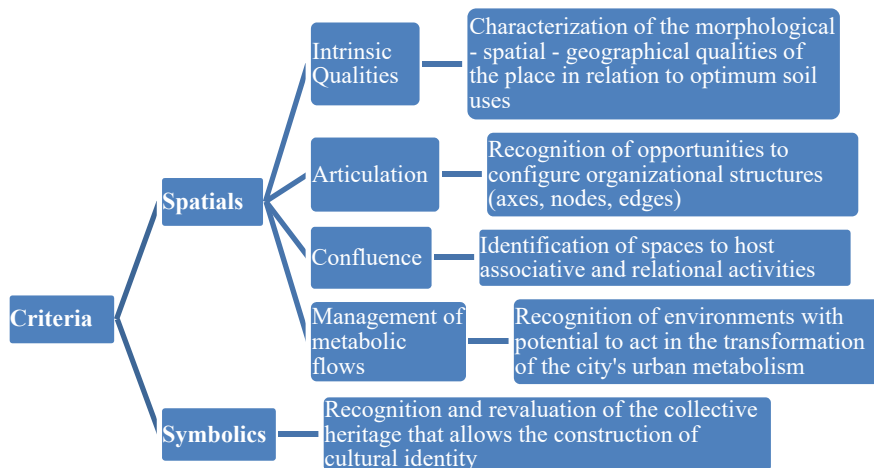


Figure 5: Criteria scheme.

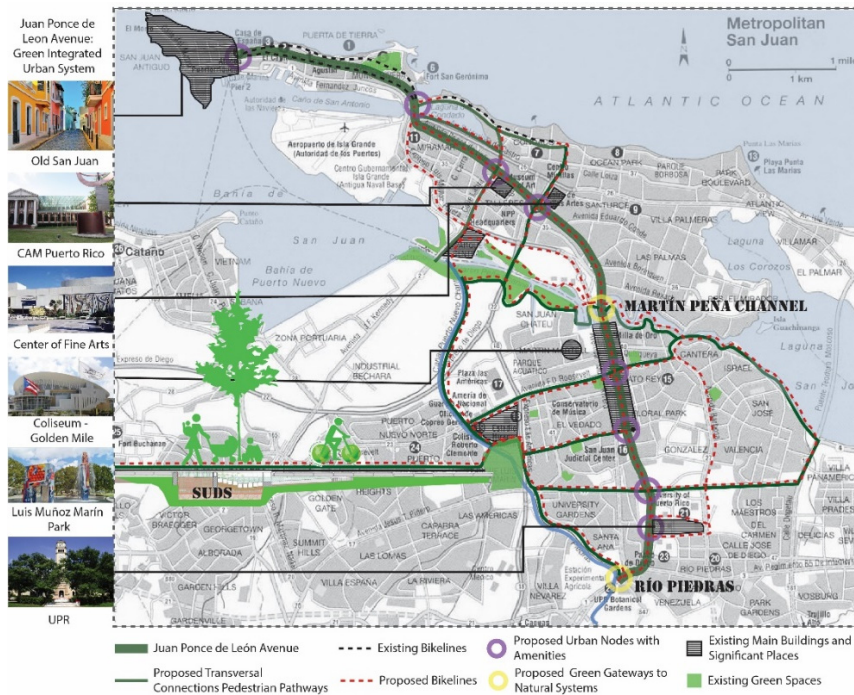


Figure 6: Proposal scheme.

7 CONCLUSIONS

The street loses its metabolic function as the crops disappeared from the periphery and the cistern discarded because the water can be driven to the city from remote places. Most of the current roadway infrastructure was developed based on guidelines that emphasize vehicle mobility and safety and minimizing short-term upfront costs, with less consideration given to social and environmental aspects. This paper raises to retake the role that the history of the street shows us. So, this proposal is addressed to restore and enhance its original value as functional, aesthetic, social and cultural configurator of the city with minimal impacts.

Achieving sustainable urban streets can create more liveable communities. With amenities nearly located, individuals would be more likely to utilize alternative mode choices such as walking, biking or transit, which leads to improved urban health. Streets busy with pedestrian and bicycle traffic are safer and strengthen a sense of community.

This work provides a view of Avenida Juan Ponce de León from its latent heritage, which can be exalted through a reconfiguration of its urban metabolism. This reconfiguration represents an opportunity to lead San Juan towards a more sustainable city scheme.

Further investigations will provide planners, designers and decision makers with a precise understanding of the dynamic flow patterns in San Juan.

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