A structural analysis method for the promotion of Mexico City’s integral plan of mobility

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Abstract: Transportation system and its Urban Transportation Infrastructure (UTI) influence an area’s economic health and quality of life because they provide the background in order the people to perform their everyday activities. Nevertheless, transportation activity generates certain negative externalities like congestion, road accidents, poor air quality that affect the people physically, emotionally and socially. These externalities become severe via the urbanization-metropolisation phenomenon that increase the distances for territorial displacement, generating major mobility demand and car usage. Consequently, an approach to urban planning is required, which would prioritize sustainable mobility. This paper’s objective is to help the implementation of Integral Mobility Plans by focusing on the case of Mexico City. This can be achieved through the application of structural analysis method in two steps: first, we facilitate the identification of the interlinks among the essential urban structure’s components for sustainable mobility. Second, we evaluate the effectiveness of the public policies-strategies that form part of Mexico City’s Integral Mobility Plan and organize them in order of importance. The results show which UTI elements should be considered primarily for sustainable mobility.

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PUBLIC INTEREST STATEMENT
Transportation systems help shape an area’s economic health and quality of life, by providing the necessary infrastructure for the mobility of people and goods. Therefore, the transport sector is an important component of the economy and a common tool used for economic development. However, transportation and the extensive automobile usage are responsible for several negative externalities such as congestion, poor air quality and road accidents that affect the society as a whole. Within this context, the recently elected government of Mexico prioritized the implementation of an integrated mobility plan in order to assure favourable conditions for successful urban development via better structuring mobility within the city. This work tries to help the implementation of integrated mobility plans through the creation of a global index related to urban structure management and the evaluation of several public policies-strategies according to their impact upon the previously mentioned index.
and which public policies-strategies should be prioritized in order to implement the aforementioned plan effectively.

**Subjects:** Environmental Management; Environment & the City; Environmental Policy; Civil, Environmental and Geotechnical Engineering; Transportation Engineering; Sustainable Development; Urban Development;

**Keywords:** sustainable mobility; urban transportation infrastructure; structural analysis; urban planning; integral mobility plan; urban management

1. Introduction

The recent process of urban-metropolitan development requires a new way of urban planning. This is a difficult task because of the multiple variables that interact in an urban system which is functioning as a set of geographically distant, heterogeneous and interconnected territories. Moreover, it is important to mention that within the same urban system there are localities with different characteristics, needs and priorities adding an extra grade of difficulty to the matter. Hence, the transportation system and its infrastructure is one of the most pressing problems in cities today.

In recent decades, many studies and research have been done trying to find solutions. In the past two decades, the analytical literature has grown substantially with studies carried out using different approaches, such as a production function and growth regressions, as well as different variants of these techniques (using different methodologies, methods and data). Most of these studies concluded that transportation infrastructure and transportation sector in general contribute to productivity, output and growth rate (Alminas et al., 2009; Álvarez-Herranz & Martínez-Ruiz, 2012; Aschauer, 1991; Calderón & Chong, 2009; Calderon & Serven, 2008; Estache & Fay, 2009; Fan & Zhang, 2008; Khandker et al., 2009; Melo et al., 2013; Mu & Van de Walle, 2007; Schofer & Mahmassani, 2016; Zhang, 2008).

In these growth-focused studies, can be identified a bias towards economic objectives instead of social targets, hence, it is of paramount importance to highlight the impact of transportation infrastructure upon development via qualitative parameters and not only on growth through quantifiable ones (Flores et al., 2013, p. 83). For this reason, interest has increased recently around the world, but more in the United States and in Europe for the improvement of cities urban environment, in order to be transformed into a sustainable environment, where the quality of life of its inhabitants improves.

A sustainable urban transport system requires the strengthening of several features including mobility, accessibility, social equity, efficiency, security, comfort, low carbon emissions, and “friendability” towards people and the environment. To achieve all these objectives, various challenges must be addressed in an integrated way. These challenges include the improvement of human health through the reduction of urban air pollution, and the reduction of traffic accidents; control of excessive motorization; improvement of public transport services, and strengthening of active modes of transportation, considering the needs of vulnerable groups, as well as, the establishment of plans for sustainable urban mobility with its derived strategies, policies and lines of action for integral urban development (Amirazodi, 2012; Gaceta Oficial de Distrito Federal, 2014; Hoque & Alam, 2002; May, 2014; Medina, 2012a, 2012b; Pardo, 2011).

An Integrated Mobility Plan (IMP) is an important instrument formed to assure connectivity, now and in the future, between people and places. Integrated mobility plans can be performed at national, regional or local level by the authorities responsible, in collaboration with stakeholders from different sectors such as environment, energy, land-use planning or healthcare. The objective of mobility plans is to assure favourable conditions for successful urban development, via better structuring mobility within a city’s urban area. Therefore, public transport should be acknowledged as the central pillar of mobility plans, since it represents the basis of sustainable mobility (UITP, 2014).
Thus, the measures (push and pull approach) applied within the urban transport system should be able to convince the people to change their habits of territorial displacement and move from the private automobiles to public and active (cycling-walking) transport. It is about pushing the people towards sustainable transportation modes. Simultaneously, it should be offered to the people a very high quality of public transport services accompanied by the generation of neighborhoods that take into account the security and convenience of pedestrians, cyclists and users of public transport (Müller et al., 1992; Pardo, 2011).

The IMP approach came also to Mexico (at least as an idea to be promoted and implemented) via the recently elected government due to the fact that the capital of Mexican Republic as well as the Mexican Cities in general follow a 3D model (dispersed, distant and disconnected) of urban growth, characterized by a disproportionate, fragmented, and unplanned urban expansion. This model of territorial occupation is highly unproductive, because it deepens the inequality and generates high levels of pollution increasing the risk of climate change. (CTS EMBARQ, 2013, p. 31).

This paper’s objective is to help the implementation of integrated mobility plans by focusing on the case of Mexico City. This can be achieved through the application of structural analysis method in two steps: first, we facilitate the identification of the interlinks among the essential urban structure’s components for sustainable mobility. Second, we evaluate the effectiveness of the public policies-strategies that form part of Mexico City’s Integral Mobility Plan and organize them in order of importance.

However, it should be noted that this work is based on the work of Chatziioannou and Alvarez-Icaza (2017a, 2017b) but it has some important differences that could enrich the above-mentioned investigation and provide genuineness to the present study. Firstly, in this paper is going to be implemented an analysis of sensitivity in order to characterize the relationships between the selected indicators (strong, medium or weak relationships) that will permit a more realistic hierarchy (via structural analysis) among the indicators and secondly is going to be taken into account within the calculation of mobility’s quality, the area that every block covers in order to evaluate the level of functionality and coverage of various UTI elements and urban surroundings related to the sustainable modes of transport.

The paper is structured in the following way, in Section 2 and in Section 3 the conceptual framework of this study is established through the presentation of the actual problematic situation and the new government’s proposal of the Integral Mobility Plan. In Sections 4 several UTI and urban surrounding’s indicators related to sustainable mobility and to the aforementioned plan are going to be structured in a hierarchical manner in order to create a decision-making instrument related to UTI management in the form of a weighted index and to evaluate public policies-strategies associated to these indicators. Section 5 gives some conclusions and future research on this approach.

2. The current situation of urban management and urban growth in Mexico City
The real estate market determines the current model of urban growth and until today it has been predominantly dispersed, disordered, with low densities, without mixed land uses and unsustainable. The lack of urban planning has resulted in the fragmentation of the territory and has increased the transportation distances and thus the time required for it.

The massive construction of houses has reached an unprecedented scale. Between 2003 and 2010, the National Workers Housing Fund Institute (INFONAVIT in Spanish) contributed with more than 3.2 million in credits. An amount greater than the total granted over the last 30 years (ITDP, 2012a, p. 15).

However, the deficiencies and the poor planning in the massive construction of social interest housing have resulted in the abandonment of 26% of the housing finance, and in 21% of these cases, the main cause for this negligence is the distance between their houses and the city (urban sprawl) as well as the lack of efficient public services to meet the transportation demand (ITDP, 2012a, p. 15). Besides,
the majority of these houses is built by the residents and is isolated from the rest of the road network; they lack an appropriate infrastructure that could provide them with a network vision that would connect them with the rest of the road organization (Towle, 2011).

Real estate developers have a tendency to purchase cheap land on the outskirts of the city, the acquisition of these lands and their land-uses to build housing estates has become increasingly frequent. The construction of these assemblies has been carried out as urbanization models of island cities. As a result, these urban structures are only linked to their environment and to the metropolitan region by one insufficient and inadequate road to meet their collective demands. Besides, these housing projects lack the commercial, educational, health or transportation services and this is the reason why people choose to abandon them almost immediately after their purchase (Duhau, 2008, p. 21–27).

The current housing policy is responsible for the fragmentation of the urban space, for increasing distances and transportation times and for endangering the environmental and the territorial structure of Mexican cities. As a result of its dispersed development pattern with low densities and mixed land uses, it forces the citizens to live less the city, to cover longer distances, to use the car more often and walk less (ITDP, 2012a, p. 17). This isolation demands the expenditure of a greater amount of energy for transportation and for road space allocation, a phenomenon that is reflected in the majority of Mexican cities that show a faster increase in the number of private cars in comparison to its population.

The constant growth in the number of vehicles and the intensive use of the cars generates social, economic, and environmental costs which are not exclusively covered by the drivers but by the society as a whole (ITDP, 2012a, p. 18). It must be added that 65% of the investments (investments which are a product of policies) in the mobility sector are intended to be used in road infrastructure for private cars. We were able to identify the fact that an average of only 22% of these, were committed to public transport and even a lot less to the cycling and pedestrian infrastructure (9% and 4%, respectively) (Nieto Enríquez, 2014).

All this has led to a gradual but increasing occupation of the urban spaces in order to construct urban roads that in turn are invaded by different types of vehicular units (predominantly private) clogging up the roadways and increasing the automotive traffic congestion, with an impact on the demand for road and parking places to respond to the increasing vehicular number. This severely worsens the phenomena of congestion and inefficiency of urban roadways; particularly the main corridors of metropolitan scope as well as the phenomena of road accidents, noise, poor air quality among others.

Moreover, there are no comprehensive approaches towards issues such as urban development policies, public space, environment, public transportation, and non-motorized transportation (cycling and walking). Even if there are justifications for large investments in infrastructure for cities and people-oriented mobility, little importance is given to the search for solutions that minimize the environmental impact, such as the reduction of energy consumption and the usage of private cars (ITDP, 2012a, p. 22).

In 2008 the pollution generated by gasoline combustion was connected to 14,000 deaths and it can also be mentioned that traffic accidents caused 24,000 deaths, 40,000 disabled and 750,000 injured (OMS, 2012). The annual cost of these accidents was around 126 billion pesos, which is equivalent to 1.3% of the National GDP (Cervantes Trejo, 2009, pp. 100–101).

Transportation is a fundamental activity for the modern economies, nevertheless there are also some negative externalities related to transportation, for example, the private cars are responsible for generating the majority of greenhouse emissions and several distinct pollutants, these emissions contribute to climate changes which could have serious consequences in terms of health and environmental costs (Galindo et al., 2006).
The losses only for negative externalities generated by the excessive use of private cars represent 5,379 pesos per capita, or the equivalent to 4% of the total GDP of five large metropolitan areas that concentrate 40% of the national urban population (Medina, 2012a, 36–37). The future prospect in Mexico is that this situation will get worse if the use of cars continues to grow. In Table 1 can be seen the estimation of the negative externalities related to the usage of private cars in selected Mexican metropolitan areas.

More recently (SEMOVI, 2019), the Ministry of Mobility (SEMOVI) published the central guidelines of the new strategic plan of mobility in Mexico City as well as the general diagnostics of the actual problematic situation. As a resume it can be said that the problematic situation can be divided into three categories:

2.1. Fragmentation
Nowadays, the travel times in Mexico City and its metropolitan area increase steadily. This is due to the unequal distribution of travel destination areas and to the lack of coverage, disconnection and serious operational flaws of mass transit networks. Moreover, there is no integrated vision of the mobility concept in Mexico City, the city's mobility policies are delinked from territorial occupancy-land use policies and programs. As a result, there is no comprehensive traffic management aimed at giving fluidity and safety to the displacement of different transport modes, this is compounded by the lack of a metropolitan perspective, which fails to understand Mexico City and its suburbs municipalities as a single mobility system. Finally, the city's cycling infrastructure is scarce, disconnected, concentrated in the city’s central areas and there is no comprehensive policy of freight transport.

2.2. Abandonment
It is estimated that 101 trains of the “Metro” mass transit system are out of operation, while the failures of the operational ones are continuous. Only in 2017 were presented 22.195 systems failures, generating delays to millions of people. The electrical transport system (trolleybuses and light rails) has a more acute crisis. Its 300 trolleybuses exceed 20 years of useful life, its fleet has been reduced by 12% since 2017 and only 63% of the remaining trolleybuses is in operation. In addition, a third of the light rail fleet is out of operation for a variety of reasons. The RTP bus system has recently (the last 2 years) acquired new units; however, 27% of its public service fleet is out of operation. Only the Metrobus system (BRT) has received investment for its growth, but 7% of its fleet is in maintenance and has saturation problems that reduce the quality of travels.

2.3. Inequality
The average times of transfer are greater in the sector of public transport, in which 50% of the City’s trips are made. Mobility has a spatial pattern of inequality between the urban center and its periphery. Most public transport trips start on the periphery from 4 am to 10 am. There are transfer times greater than one and a half hours around the central areas of Mexico City, both for the travels of men and women (SEMOVI, 2019).

Low-income passengers are forced to curtail the number of trips that they make, use modes of transport that do not incur a direct cost, such as walking or cycling, or to live in locations that minimize their transport costs. In Mexico City, household surveys revealed that households were spending up to 25% of daily earnings on transport (SUTP, 2018). Further inequalities are documented in terms of gender issues and differences in mobility patterns.

3. The new mobility paradigm in Mexico City
To reduce the pressure on the urban transportation system, the Ministry of Mobility (SEMOVI in Spanish) proposed a new mobility paradigm for the creation of a modern mobility hierarchy (Gaceta Oficial de Distrito Federal, 2014, p. 52). Next figure shows the current proposal:
Table 1. Estimation of the negative externalities related to the usage of private cars in selected Mexican metropolitan areas, based on (Medina, 2012a, p. 37)

| Area             | LOCAL SMOG | CLIMATE CHANGE | ACCIDENTS | CONGESTION | NOISE | TOTAL   | % OF GDP |
|------------------|------------|----------------|-----------|------------|-------|---------|----------|
| Valley of Mexico | 14,396     | 6,718          | 10,332    | 82,163     | 8,320 | 121,930 | 4.6%     |
| Monterrey        | 2,282      | 1,065          | 5,843     | 11,485     | 1,319 | 21,994  | 2.8%     |
| Guadalajara     | 2,795      | 1,304          | 4,970     | 10,635     | 1,615 | 21,319  | 4.7%     |
| Puebla-Tlaxcala | 996        | 465            | 1,317     | 1,894      | 575   | 5,247   | 1.8%     |
| León             | 506        | 236            | 1,250     | 321        | 293   | 2,606   | 1.6%     |
| TOTAL            | 20,975     | 9,787          | 23,712    | 106,498    | 12,123| 173,095 | 4.0%     |
Through Figure 1, it is obvious that the traditional transportation paradigm related to greater supply of road infrastructure in order to improve the flow of vehicles has expired. Nowadays, it is important to change the habits of displacement and encourage the efficient use of transportation modes. By that way, it will be easier to achieve public policy objectives associated with the idea of push & pull travels.

Since the ideal is to push travels away from the private transportation modes (automobiles) and pull them close to the sustainable transportation modes (walking, cycling, public transportation); This with the aim of managing the urban mobility towards sustainability (Medina, 2012b, p. 37). Therefore, every step of the pyramid needs to be associated with some of the respective UTI elements related to each mode of transportation. This means that according to the new paradigm, the UTI connected to the pedestrians, cyclists and public transportation, needs to be attended first in order to manage adequately the sustainable mobility. This change that intends to give priority to pedestrians will require a new way to see, think, build, maintain and improve certain infrastructure of which almost nothing is known, because everything has, until now, been focused towards cars.

The recently elected government of Mexico City in order to neutralize the actual problematic situation in terms of mobility and to support the new mobility paradigm, proposed an Integral plan of Mobility with its associated strategies, policies and lines of actions that can be seen in the figure that follows (Figure 2).

4. Methodology and results
This work is oriented towards mobility and its significance for the planning of urban infrastructure in Mexico City by making use of the sustainable mobility paradigm (Banister, 2008; ITDP, 2012a). The aforementioned paradigm gives importance to the promotion of efficient transportation modes by changing the people's mobility habits. Hence, the actions of urban planning need to focus upon the establishment of a user-friendly environment through the sufficient coverage and functionality of the UTI elements and its urban surroundings related to the sustainable transportation modes.

As a consequence, several indicators associated with public and active transport modes are constructed via available public information in form of shape files and tabular data. The aforementioned information is accessible by the National Statistical Directory of Economic Units (DENUE in Spanish), the Ministry of Constructions and Services (SOBSE), The Ministry of Mobility (SEMOVÌ) the Ministry of Urban Development and Housing (SEDUVÌ) and the National Institute of Statistics and Geography (INEGI).
As a case study, the indicators are implemented to the most populated Census Tract (CT) of Iztapalapa County. Hence, it is possible to evaluate the coverage and functionality of the UTI and its urban surroundings elements related to sustainable mobility so that to generate a global index based upon the previously mentioned indicators.

The global index consists of two parts, the first one is called variable and results from the implementation of the indicators in a CT of Iztapalapa County via a Geographic Information System (GIS) (Table 2). The second part is the constant one (Table 1) and is the outcome of the experts opinion, resulting from the structural analysis method, the constant part is the same for every CT as is defined by the dependency and influence levels of each indicator. However, before moving forward, it would be useful to provide a brief representation of the method (structural analysis) that is going to be used for the interrelations of UTI and urban surroundings elements.

4.1. Structural analysis overview

The structural analysis is one of the most frequently used instruments in prospective studies. The first structural analysis justifications can be attributed to Jay Forrester, for his study with models of urban and industrial dynamics in 1961. Meantime, the necessity to take into account several quantitative and qualitative variables influenced the pioneers of structural analysis to enrich it by using representation modes such as tables and charts (Ballesteros Riveros & Ballesteros Silva, 2008).

With this point of view, Wanty and Federwish (1969) implemented the structural analysis method to an air transportation and to an iron-steel company. Later Teniere-Buchot provided evidence related to the analysis of “water” system through the publication of an article about a model associated with the policy of water pollution (Arcade et al., 1993). At the same time, Kane (1972) presented the KSIM model that is based upon the method of structural analysis. For his part, Roberts (1971) conducted investigations so that to identify interlinks among applications associated with pollution and energy consumption in the sector of transportation. Shortly after in France, Duperrin and Godet (1973) proposed a structural analysis method for the hierarchical organization of variables related to nuclear power.

More recently, Sharma and Gupta (1995), examined waste management via structural analysis. Arya and Abbasi (2001), in turn, implemented structural analysis for environmental analysis purposes. Furthermore, Kanungo et al. (1999) used structural analysis for the qualitative evaluation of information systems effectiveness. In addition, the structural analysis has
| Indicator                                      | Actual values of CT | Description-Criteria in order to evaluate the CT according to each indicator |
|-----------------------------------------------|---------------------|--------------------------------------------------------------------------------|
| Street lights                                 | 13                  | Number of blocks that have streetlights in every front within the examined CT. |
| Semi-fixed Merchant stands                    | 11                  | Number of blocks that have semi-fixed merchant stands in every front within the examined CT. |
| Roadside Merchant stands                      | 12                  | Number of blocks that have roadside merchant stands in every front within the examined CT. |
| Pedestrian bridges                            | 2                   | Number of blocks that have pedestrian bridges in any of their fronts within the examined CT. |
| Sidewalks                                     | 5                   | Number of blocks that have sidewalks in every front within the examined CT. |
| Ramps                                         | 5                   | Number of blocks that have ramps in every front within the examined CT. |
| Sidewalk fittings                             | 5                   | Number of blocks that count with sidewalk fittings in every front in the examined CT. |
| Road networks of motorized transit            | 6                   | Number of blocks that have high or medium level of connectivity within the selected CT. It was chosen this kind of connectivity level due to the fact that the principal roads of motorized transit facilitate the coverage of public transit because of their physical dimensions. |
| Coverage of public transport                  | 18                  | Number of blocks that have coverage of public transport in any of their fronts. |
| Stations of public transport                  | 2                   | Number of blocks that count with public transport stations in any of their fronts in the selected CT. |
| Population’s concentration                    | 15                  | Number of blocks that have population’s concentration greater than the average population’s concentration within the Iztapalapa County. |
| Land use                                      | 23                  | Number of blocks that count with mixed land use. Nevertheless, it is noteworthy to highlight that we decided to qualify all of the CT blocks as mixed, due to the existence of several points of interest around the blocks that cover human needs, transforming the area as a high candidate in terms of attraction and generation of trips. However, the officially registered land use type of the blocks with the examined CT is residential and possibly this discrepancy between the official registered land use and the one that we qualified the blocks is the result of the inexistence of the points of interest when has been officially registered the land use type. |
| Proximity to points of interest               | 23                  | Number of blocks that count with points of interest within an acceptable pedestrian distance (750 m) in the examined CT. All the blocks count with points of interest that cover distinct human necessities, qualifying the CT as complete neighborhood. |
| Block’s self sufficiency                      | 23                  | Number of blocks that count with points of interest that cover distinct human necessities such as security, survival, work, education, socialization, access to public transport etc. at an acceptable pedestrian distance, qualifying the blocks of the CT with high-very high auto-sufficiency level. Equal to the case of the previous indicator the CT has the capacity to transform into a complete neighborhood. |
| Bike lanes                                    | 0                   | Number of blocks having bike lanes in any of their fronts within the selected CT. At the moment there are no bike lanes in the examined CT. |
| Block’s size and form factor                  | 7                   | Number of blocks that have regular form or close to regular form and small area in the examined CT. |
| Trees                                         | 0                   | Number of blocks that have sufficient coverage of trees (in every front of the block) within the selected CT. |
been utilized in conjunction with existing international relations theories so that to recognize, specify and foresee the structure of international conflict (Kim & Barnett, 2007, pp. 135–165). Qureshi et al. (2008) applied the structural analysis method to provide guidelines of 3PL provider’s services.

The structural method seeks to analyse in a qualitative way the relationships between the variables that make up a system within a company, organization, society, country, etc. In addition, it relies on the qualitative judgment of actors and/or experts who are part of a system. The different phases of the MICMAC method according to Arcade et al. (1993) are as follows:

- Fase 1: Inventory of system’s variables.
- Fase 2: Description of system’s variables relations.
- Fase 3: Identification of essential variables and key factors.

4.2. Methodological proposal for enhancing the integral mobility plan

This study aims to clarify the interconnections among different UTI-urban surrounding elements associated with sustainable transportation modes, so that to organize these indicators in order of importance and create a global index. Then, the hierarchically organized indicators are going to be connected to the strategies and public policies belonging to Mexico City’s Integral Plan of Mobility in order to assess their effectiveness according to their impact upon the generated global index. The methodological approach can be appreciated in the following lines.

4.2.1. Inventory of system’s indicators

At this stage, a list that includes all the indicators considered for this study and constructed as part of the system in order to enhance the Integral Plan of Mobility can be seen in Table 3.

4.2.2. Description of system’s indicators relations

The objective of this stage is to connect the indicators taken into account for this study within a matrix of double entry (Figure 3). The double entry matrix reflects at each row’s level the

| No | Name of Considered Indicator | Codification of Indicators in MICMAC Software |
|----|------------------------------|---------------------------------------------|
| 1  | Street lights                | Street lig                                  |
| 2  | Semi-fixed Merchant stands   | Semi-fixed                                  |
| 3  | Roadside Merchant stands     | Roadsidest                                  |
| 4  | Pedestrian bridges           | Pedebridge                                   |
| 5  | Sidewalks                    | Sidewalks                                   |
| 6  | Ramps                        | Ramps                                       |
| 7  | Sidewalk fittings            | Sidefittin                                   |
| 8  | Road networks of motorized transit | RoNeMoTr                                |
| 9  | Coverage of public transport | PubTraCov                                   |
| 10 | Stations of public transport | Stations                                    |
| 11 | Population’s concentration   | Popuconce                                   |
| 12 | Land use                     | Labd use                                    |
| 13 | Proximity to points of interest | ProxiPOIs                                |
| 14 | Block’s self sufficiency     | Self-suffi                                  |
| 15 | Bike lanes                   | Bike lanes                                  |
| 16 | Block’s size and form factor | Bickforlac                                  |
| 17 | Trees                        | Trees                                       |
influence that an indicator exercises upon the others. At the same time, the matrix reflects at a column level the influence that each one of the considered indicators experience by the others (Romero Perea, 2012).

In this paper we are going to focus our efforts in the established indicators ponderation process due to the fact that in the work by Chatziioannou and Alvarez-Icaza (2017b) only ones (“1”) and zeros (“0”) has been used for the description of the indicator’s relationships, missing by that way valuable information about the importance of each indicator. Hence, for each pair of indicators, the following questions are going to be settled: is there a relationship of direct influence between the indicators i and j? If it does not exist, record 0; otherwise, we need to evaluate whether this relationship of direct influence is weak (1), medium (2), strong (3) or potential, by linking the indicators with each other we have the following matrix:

Nonetheless, it is worth mentioning that the matrix of direct relations is the product of a consulting process with various experts through which we were able to discover relations between indicators that at first were not obvious (Figure 4). We tried to keep the group of experts consulted as interdisciplinary and as independent as possible, firstly, because of the sustainable mobility paradigm’s nature that demands interdisciplinary approaches and secondly in order to avoid the phenomenon of leaders.

Thus, the experts consulted come from various fields, such as transportation and sustainable transportation experts, geographers, experts in matters of energy consumption, experts in urban planning and territorial organization, experts in public policies-strategies related to the sustainable paradigm as well as decision makers within the institutions responsible to manage the UTI and its urban surroundings.

4.2.3. Identification of the essentials indicators

The objective of this step is to detect the indicators of greater importance. They are detected in terms of influence upon other indicators, as well as in terms of dependence (Colodni, 1987, p. 3). In order to achieve it, we need to measure both the direct and the indirect relationships between the indicators, this is possible via the MICMAC method (Arcade et al., 1993).

The direct qualification is easy, as it means simple sums of values of influence and dependence for each of the considered indicators, while the indirect classification is obtained after the power
elevation of the matrix of direct relations. The elevation of the matrix to the square shows the relations of order 2 between two indicators; the elevation of the matrix to cube reveals the relations of order 3 and so on. It is necessary to raise the direct relationship matrix as many times as necessary until the results stabilize; that means until the influence and dependence of the matrix’s indirect relations to the next does not alter in terms of importance and thus we can set the hierarchy between the selected indicators (Guzmán Vazquez et al., 2005, p. 27).

Through the MICMAC software, we were able to raise the matrix to successive powers (1, 2, 3, etc.). The matrix has been raised to 3 because at that iteration was stabilized and the indirect relationships were obtained. At the end of the process, we have the matrix of indirect relations, which is represented graphically in Figure 5.

4.3. Results

4.3.1. Indicators hierarchical organization

The indicators located to sector 2 (Table 4) are very influential and dependent at the same time, having the capacity to generate instability to the overall systems behaviour if not treated accordingly. Within a sustainable mobility framework, the most important users are the pedestrians, followed by the cyclists and the users of public transport. Hence, we are able to see in sector 2 two indicators related to active modes of transportation (sidewalks and bike lanes) and two indicators associated to public transport (stations and coverage of public transport).

Accessibility and urban planning are very important factors for the establishment of sustainable-integrated mobility, because pedestrians, cyclists and users of public transport are not capable to cover long distances, hence, they need ease of access to urban structures and densification of land use in order to cover their needs of mobility and compete with motorized modes of transport. Consequently, in sector 2 are located two indicators related to urban planning such as land use and block’s self-sufficiency.
Finally, at the same sector it is located the road network of motorized transit because concerning topological criteria it can be characterized as the backbone upon which several of the other considered indicators are constructed, for instance, the road networks define where the streetlights, pedestrian bridges, sidewalks, sidewalk fittings and stations of public transport should be constructed.

However, the indicators located in sector 1 (Table 4) are also very important, because they are highly influential and therefore are able to impact the system’s behavior. In this sector are located two indicators associated with urban planning, the proximity to POIs indicator and the block’s size and form factor indicator. The block’s size and form factor indicator it is important to consider for the transition from hierarchical to well-connected networks, and for the renovation of public space’s image. The proximity to POIs is associated to the concept of complete neighborhoods and to the reduction of car dependence since the closer to a reasonable walking distance there are POIs that meet various human needs, the lesser will be the use of the car and the negative externalities generated by it.

The last indicator located in sector 1 is the indicator of total population within a block, which is important to consider within the framework of TOD type and cyclists oriented policies, as the construction of bike lanes and the creation of TOD development should be implemented in geographical areas that have a high population concentration.

Then in order of importance follow the indicators located in sector 3 (Table 4), they are highly dependent and therefore should be treated via the indicators from which they depend. In this sector, we can find indicators such as ramps, streetlights, sidewalk fittings and pedestrian bridges that are highly influenced by sidewalks, bike lanes and road networks of motorized transit,
respectively. In sector 4 (Table 4) we can find the so-called autonomous indicators such as merchant stands and trees that have low levels of dependency and influence. This does not mean that they are not important indicators within the context of sustainable mobility, they are simply disconnected with the rest of the indicators and as a result have a lower score.

The next step is to apply upon the aforementioned indicators a normalization process via the formulas (1) and (2) so that to assess the significance of each indicator according to their location at the four sectors (Chatziioannou & Alvarez-Icaza, 2017b).

\[ V_i = \frac{a_i}{a_{i \text{max}}} \]  
\[ V_d = \frac{a_d}{a_{d \text{max}}} \]

where \( a_i \) and \( a_{i \text{max}} \) are the actual value and the maximum value of influence for each indicator as they result when the stability of the matrix (Figure 3) was achieved, while \( a_d \) and \( a_{d \text{max}} \) is the actual value and the maximum value of dependence, respectively.

After the calculation of the actual values of the examined CT (Table 2), and the associated weights for each one of these as they result by taking into consideration the opinion of the experts (Table 5), we are able to measure the quality of mobility via a global index according to the functionality and coverage of UTI and its urban surroundings elements. Nevertheless, it is worthy to highlight that in this paper we decided to include the size factor of the blocks within the calculation process of mobility’s quality because we wanted to distinguish a well-equipped block of a big area from a well-equipped block of a small area due to their distinct levels of mobility demand that generate and by that way to make the global index seen in Equation (3) more realistic. In Table 6 can be appreciated the values of each indicator according to the area that the well-equipped or well-qualified blocks cover for each of the 17 indicators in relation to the total area of the examined CT.
where i is the value of each one of the 17 indicators with its associated weight, n is the indicator’s number (in our case they are 17), k is the number of blocks that belong to the examined Census Tract i, At is the total area of the examined CT and A is the area that is covered by the blocks that present compliance according to the best possible criteria for each of the 17 indicators.

Thus, in the following lines, we are able to see the actual performance value of the examined CT according to the mathematical formula (3).

$I(i) = 3.51$

4.3.2. Logical connections between strategies-public policies and the selected indicators
The performance value resulting from the mathematical formula (3) can be greatly improved if there are upgrades in terms of coverage of certain UTI elements and urban surroundings elements, such as an increase of sidewalks, sidewalks fittings, ramps, bike lanes, coverage of public transport, streetlights, trees, etc. Nevertheless, these lines of actions need to be part of a comprehensive plan with its strategies-public policies rather than a number of partial implemented countermeasures. Hence, in this section of the paper logical connections are going to be created between the indicators considered for this study and certain strategies-public policies with their associated lines of action that belong to the integral plan of mobility (SEMOVI, 2019) and are related to sustainable transportation.
Table 7 contains the PIM with its respective strategies and public policies, they also contain a description of the policies as well as the key indicators identified by the MICMAC method connected with the policy-strategy presented.

The three strategies of Mexico City’s PIM (integrate, improve and protect) can be interlinked through their derived policies to the identified as key indicators in order to generate the corresponding lines of actions (Table 7). The most important strategy is the “protect” one and more specifically the urban development public policy because includes the majority of the identified “key” indicators. Then, we have the “integrate” strategy with its associated public policies and indicators, where of first importance in terms of effectiveness upon the global index is the policy oriented to cyclists, then follows the “integrate” strategy associated to sustainable transportation modes and finally the “improve” strategy associated to public transport.

Concerning the lines of action effectiveness, the most effective is the one related to “protect” strategy that is related to the increase of non-motorized and public transport mobility through the establishment of the adequate coverage and functionality of the associated infrastructure. Then, follow two lines of action coming from the “integrate” strategy. The first one is associated with the establishment of sustainable mobility’s alternatives at a reasonable pedestrian distance in order the people to perform their daily activities without the necessity to use the car.

The second one is related to inter-modal transport as its objective is to construct bike lanes that preferably are close to routes and stations of public transport, as well as, close to areas with mixed land use type. The last of the most effective lines of actions belong to the “improve” strategy and has as a purpose the increase of public transport’s efficiency via the installation of public transport’s stations of high capacity in the blocks that have a high level of population’s concentration.

5. Conclusions
The majority of Mexican cities follow a 3D model (dispersed, distant and disconnected) of urban growth, characterized by a disproportionate, fragmented, and unplanned urban expansion. This
| Strategies | Strategy definition | Derived Policies | Identified Key Indicators | Corresponding lines of action |
|------------|---------------------|------------------|---------------------------|------------------------------|
| Integrate  | Integrate the city's different transport systems in order to promote walking, cycling and usage of public transport. | Policies oriented to sustainable modes of transportation | Sidewalks, Proximity to POIs, block's self sufficiency | Construct sidewalks in every front of the blocks within the examined CT. |
|            |                     |                  | Coverage and stations of public transport, block's size and form factor, bike lanes and road network of motorized transit. | Enhance the densification of land use through the establishment of proximity level at a reasonable pedestrian distance, as well as, the establishment of block's self sufficiency to a very high level. |
| Integrate  | Integrate the city's different transport systems in order to promote walking, cycling and usage of public transport. | Policies oriented to cyclists | Coverage and stations of public transport, bike lanes, land use and road network of motorized transit. | Construct bike lanes that preferably are close to routes and stations of public transport, as well as, close to areas with mixed land use type. |
|            |                     |                  | Bike lanes, population | Construct new bike lanes. |
| Improve    | Improve the infrastructure and existing transport services with the object of increasing the accessibility of the people, decreasing transfer times, improving travel conditions and making more efficient the transportation of goods. | Policies oriented to the accessibility of people. | Coverage and stations of public transport, population and road network of motorized transit. | Locate stations of public transport of medium-high capacity in the blocks that have a high or medium level of connectivity, as well as, high population's concentration. |
|            |                     |                  | Coverage and stations of public transport | Increase the public transportation coverage in the blocks that do not count with public transportation modes (expansion of public transportation services, develop BRT, confined lanes etc.). |
|            |                     |                  | Sidewalks | Secure the existence of pedestrian UTI that is necessary for getting on and off the transportation modes. |
| Protect    | Protect the users of different systems of transport through the provision of infrastructure and via inclusive, worthy and safe services. | Policies oriented to urban design | Coverage and stations of public transport, land use. | Enforce the existence of mixed land use around the stations of public transport. |
|            |                     |                  | Coverage and stations of public transport | Establish coverage of public transport with its respective elements in the blocks that do not have public transportation service. |
|            |                     |                  | Coverage and stations of public transport, sidewalk, proximity to POIs, block's self sufficiency, bike lanes and block's size and form factor. | Increase the non-motorized and public transport mobility through the establishment of the adequate coverage and functionality of the associated infrastructure. |
|            |                     |                  | Coverage and stations of public transport, population. | Establish neighborhoods associated to TOD where there is a high concentration of people. |
|            |                     |                  | Coverage and stations of public transport, proximity to POIs | Establish neighborhoods associated to TOD where there is a high concentration of POIs. |
model of territorial occupation is highly unproductive, because it deepens the inequality and generates high levels of pollution increasing the risk of climate change. (CTS EMBARQ, 2013, p. 31).

Integral mobility plans are powerful tools to help cities reduce the environmental, economic and social impacts generated by fragmented mobility systems that prioritize the use of private automobiles. Developing these plans requires decision-makers to understand the complexities of mobility planning as the guiding axis of urban development. Only by integrated planning these two sectors, the mobility of Mexican cities can be adequately managed (ITDP, 2012a).

This paper can contribute to promoting and organizing hierarchically transportation-urban planning policies belonging to an Integral Mobility Plan, which can mitigate the problems of urban-metropolitan regions with respect to inaccessibility and private automobiles overuse. It is expected that a strategy or policies of integrated mobility can play their role in alleviating the low-income families (that do not have necessarily the opportunity to own a car) by reducing the times needed for territorial displacement via alternative transportation modes, improving by that way the competitiveness of population, urban development and quality of life.

Taking into account this reality, this investigation applied the structural analysis method in order to help the implementation of integrated mobility plans by focusing on the case of Mexico City. This can be achieved in two steps: first, we facilitate the identification of the interlinks among the essential urban structure's components for sustainable mobility. Second, we evaluate the effectiveness of the public policies-strategies that form part of Mexico City’s Integral Mobility Plan and organize them in order of importance.

The soundest part of this study is the construction of a participative synthesized index that has the capacity to measure the quality of sustainable mobility through the coverage and functionality of UTI-urban surroundings indicators. In addition, through the previously mentioned index and via the establishment of logical relationships between the indicators and public transportation policies we are able to identify which indicators are the key ones within the framework of the policies and consequently to identify which strategies-public policies with their associated lines of actions are the most effective in accordance with their impact on the synthesized index.

Our findings indicate through the MICMAC software that the most important indicators for sustainable mobility are the proximity to the points of interest, size and form factor of the block, coverage of public transport, total population of the block, land use, block’s self-sufficiency, sidewalks, road networks of motorized transit and stations. Consequently, the most important strategy is the “protect” one and more specifically the urban development public policy because includes the majority of the identified “key” indicators. Then, we have the “integrate” strategy with its associated public policies and indicators, where of first importance in terms of effectiveness upon the global index is the policy oriented to cyclists, then follows the “integrate” strategy associated to sustainable transportation modes and finally the “improve” strategy associated to public transport.

Moreover, it is worth mentioning that by taking into account the intensities between the indicators relations we were able to produce a smoother distribution of the indicators within the four quadrants as many indicators passed from the second quadrant to the third one revealing by that way their high grade of dependence and the necessity to handle them through the indicators from which they depend. Also, it is useful to highlight that by taking into account the size factor of each block we were able to produce a more realistic global index that do not overestimate the well qualified (well equipped) blocks but prioritize the management of bigger blocks due to the superior mobility demand that generate.

Furthermore, in relation to the synthesized index, there is the need to find efficient ways to complement this set of indicators, in order to help the assessment of mobility and enrich the proposed global index. Finally, it would be interesting to see how the results of the indicators weighting process (structural analysis) would have been if we would have taken into account
except form the expert’s opinion, the opinion of the common people in order to be able to compare and verify if the two perceptions were different or no according to the expert’s disciplines.

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