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UNIVERSIDAD AUTÓNOMA DE SAN LUIS POTOSÍ

FACULTADES DE CIENCIAS QUÍMICAS, INGENIERÍA Y MEDICINA

PROGRAMAS MULTIDISCIPLINARIOS DE POSGRADO EN CIENCIAS AMBIENTALES

AND

TH KÖLN - UNIVERSITY OF APPLIED SCIENCES

INSTITUTE FOR TECHNOLOGY AND RESOURCES MANAGEMENT IN THE TROPICS AND SUBTROPICS

DESIGN OF NON-MOTORIZED MOBILITY PLAN FOR WARM CLIMATE CITIES
CASE: HERMOSILLO, SONORA, MEXICO

THESIS TO OBTAIN THE DEGREE OF

MAESTRÍA EN CIENCIAS AMBIENTALES

DEGREE AWARDED BY UNIVERSIDAD AUTÓNOMA DE SAN LUIS POTOSÍ

AND

MASTER OF SCIENCE

NATURAL RESOURCES MANAGEMENT AND DEVELOPMENT

DEGREE AWARDED BY TH KÖLN – UNIVERSITY OF APPLIED SCIENCES

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SAN LUIS POTOSÍ, MÉXICO AUGUST 2016

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PROYECTO FINANCIADO CON EL APOYO DE:

DEUTSCHER AKADEMISCHER AUSTAUSCH DIENST (DAAD)

CONSEJO NACIONAL DE CIENCIA Y TECNOLOGÍA (CONACYT)

LA MAESTRÍA EN CIENCIAS AMBIENTALES RECIBE APOYO A TRAVÉS DEL

PROGRAMA NACIONAL DE POSGRADOS (PNPC - CONACYT)

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ACKNOWLEDGEMENTS

I want to thank UASLP and TH-Köln for letting me be part of the ENREM Master Programme, as well as my professors, for helping me to change my way of thinking and broaden my knowledge through several subjects and given me a big amount of new experiences.

Thanks to my family for their support and motivation for me to accomplish this goal, as well as every one of my dreams.

Thanks to CONACyT and DAAD for financing my studies in Mexico and Germany.

Thanks to Guadalupe Peñúñuri and IMPLAN Hermosillo and the Patronato Pro Obras del Centro Cívico y Comercial de Hermosillo, AC for giving me some time and providing me with plenty of information.

Thanks to Equipo Maravilla for always cheering me up and being by my side in every step of my career.

Thanks to Dr. Valente Vázquez for guiding me since the beginning of this project, always making me feel capable of doing this project.

Thanks to Herr Prof. Dr. Johannes Hamhaber for being a huge support in the process of my thesis, accompanying me through the most difficult stage of the project, always with wise comments to give.

Thanks to M.Sc. Rodrigo Díaz, for contributing to my thesis, and pushing me to explore other possibilities of research, as well as sharing your experience with me. Without you this thesis wouldn’t have been the same.

And specially thanks to all my ENREM colleagues for being my friends and my family these two years. Valentina, Edson, Joe, Laura, Clara, Andrea, Eyleen, Isabel, Melina, Martín, Nadine, Víctor y Víctor. I’ll keep you in my heart. Thanks for these two amazing years that I’ll never forget.

ABBREVIATIONS

BRT	Bus Rapid Transit
CO2	Carbon Dioxide
GDP	Gross Domestic Product
GHG	Green House Gases
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (German Society for International Cooperation)
HDI	Human Development Index
IMPLAN	Instituto Municipal de Planeación Urbana de Hermosillo (Municipal Institute of Urban Planning of Hermosillo)
MX / MEX	Mexico
PM	Particulate Matter
TOD	Transit Oriented Development
UHI	Urban Heat Island
US / USA	United States of America
WHO	World Health Organization

ABSTRACT

This research seeks to generate exploration of infrastructure elements needed to promote a proper integration of sustainable urban mobility in cities with arid or hot-dry climate, using the case of Hermosillo, Sonora, Mexico; focusing on non-motorized transport (walking and cycling, as well as promoting public transportation). This is made by analyzing the downtown area of the case study city.

The approach to this is in response to an increased use of private vehicles, which may cause economic, social and environmental problematics.

To do this it was studied the general recommendations of Transit Oriented Development. TOD is an urban model design and planning around public transport that works as a strategy to give solutions to local and regional mobility, minimizing the reliance on automobiles.

Due to the specific necessities of cities with warm climate, the research uses TOD as a baseline to generate a specific set of design principles that are specially made for arid urban environments, looking to promote a proper way to walk, cycle and use public transportation systems, despite the presence of high temperatures and other climate difficulties that can affect the performance of people in public spaces.

As a result of the analysis, design schemes were presented to apply in the area, which were set into context according to the actual information and characteristics of the study area, presenting a series of images that illustrate the proposal in its contextualized urban environment.

Keywords: *Urbanism, Transit Oriented Development, warm climate cities, urban planning, downtown.*

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CHAPTER I. INTRODUCTION

According to Lomax (1997), mobility is defined as the ability to move people and goods to their destinations in a rapid, ease and inexpensive manner, while non-motorized mobility concerns any trip made by human powered vehicles, as bicycles, skate boards and roller blades, as well as by humans and animals. (PIARC, 2008)

When cities are growing without design or control of the urban structure, division between people and the public space can result as consequence. In contemporary cities the use of particular automobiles as transportation method has been increasing among the population, nevertheless its use in an intense way generates a series of social, economic and environmental issues.

Since World War II, cities have been developing around cars, giving them priority of investment programs, increasing automobile traffic, affecting safety, comfort and environment, especially for non-motorized methods of transportation. (Gunnarsson, 2001)

Nowadays non-motorized modes of transport are being recognized as efficient and in some cases even faster than motorized vehicles in city center areas (Violato & Galves, 2014). These modes of transport tend to be used for traveling short distances or for reaching public transportation. (Baudrin, 2007)

Through history, the development of technology around automobiles has increased the ease of cars to move around the city, nevertheless, recently several organizations have been working to favor non-motorized mobility methods and public transport, because they require less space for people to move, are less pollutant and their use generates a series of positive effects in economic, social and environmental dimensions of sustainability, as well as improvements in public health.

Despite those models and design recommendations, not much is being published about specific requirements from cities with warm climates to address this issue.

This research seeks to generate exploration of the infrastructure elements required to promote an adequate integration of sustainable urban mobility in cities with arid or warm-dry climate, using the case of Hermosillo, Sonora, Mexico; focusing on non-motorized transportation means, such as walking and cycling, concentrating in the downtown area, which is a defined zone that congregates a large number of people throughout the day and the year.

I.1. PROBLEM STATEMENT

Through recent History, cities have been in a developing process which has produced extensive growing, both in developed and emerging countries, causing large trip distances for the people to do their everyday activities, favoring the use of the automobile, causing a high raise in the amount of cars on the streets.

Many cities in developing countries have created policies that make cycling and walking less attractive, which promotes that people travel by cars even in short-distance trips. In many cases the roads have no sidewalks or are obstructed by telephone and electricity poles, trees, constructed items (Hook, 2005), uneven or slippery surfaces, publicity and retail items, lack of proper infrastructure for people with disabilities, etc.

Besides, when the public transportation system is neither well structured, nor well supported by proper infrastructure and equipment, an important amount of the population can feel public transport as a non-viable option, recurring to the use of private cars.

The usage of intern combustion vehicles has also caused an affectation to the quality of air and therefore the health of the population, as well as risks like runovers and collisions.

As case of study, the city of Hermosillo in Mexico has been chosen, because it presents several issues concerning to mobility, such as extensive urban growth, bad public transportation system and poor conditions to favor walking and cycling.

In addition, one of the most important topics for any project in Hermosillo is the high temperature that can be registered in the summer, which conditions the ease for walking and using bicycles as transportation methods on the city.

I.2. JUSTIFICATION

Nowadays, urban planning presents a boom around development of policies, recommendations and guidelines for good practices. One of these approaches is the hierarchy of outdoor spaces and roads, as well as the priority for circulation. This hierarchy seeks to assign the rights, liabilities and resources to implement on the cities. Within the terms of equity in the use of public space one must prioritize the means of transportation that are more accessible to the population, which are: pedestrians, cyclists, public transportation, freight transportation and, in last instance, private automobiles, respectively. (ITDP México, 2011)

At a national level, in Mexico is estimated that between 70% and 80% of the trips that are made in the main cities of the country do not involve cars (ONU-HABITAT, 2011), despite this fact, the mean federal fund distribution dedicates 23% to mobility, for the amount of 11,763 million of Pesos –over 600 million US Dollars. (Garduño, 2012)

From this amount, 48.3% is dedicated to infrastructure for automobiles and 29.1% for paving streets, making it over 77% of the budged being given to the streets, while 11.1% is given to public transportation, 7.8% to public spaces, 3.3% to infrastructure for pedestrians and a tiny 0.4% to cycling infrastructure (Garduño, 2012), that represents a drastic contrast to the hierarchy described above. This causes inequity, always in favor to the use of cars as owners of public space.

According to information obtained from ITDP Mexico, the federal government promotes mobility plans called *“Planes Integrales de Movilidad Urbana Sustentable”* or PIMUS (Integrated Sustainable Urban Mobility Plans), nevertheless these focus on the implementation of BRT corridors in the cities, without considering the entire city and its developing, considering growth, expansion, land use, public spaces, environment, public transportation, bicycles and pedestrians, among others. Furthermore, those plans are not contemplated within the State or Local programs of planning and development. (Medina Ramírez & Veloz Rosas, 2013)

This research project looks to investigate, argument and propose design strategies of sustainable urban transportation, concerning particularly focusing on improving the accessibility for pedestrians and bicyclists from warm-climate regions, using as case of study the physical context of Hermosillo, Sonora, Mexico.

I.3. OBJECTIVES

MAIN OBJECTIVE

Design a scheme of non-motorized mobility strategies to promote better conditions for walking and cycling in warm-climate cities, using as case of study the city of Hermosillo, Mexico, focusing in the downtown area.

PARTICULAR OBJECTIVES

- Identify the main obstacles for free transit of pedestrians and bicyclists in cities.
- Describe the conditions of warm-climate cities that may work as a barrier to the free accessibility.
- Design schemes for better mobility for pedestrians and bicyclists in warm-climate cities.
- Propose changes improve conditions for non-motorized mobility, applied to the case-study area.

I.4. STRUCTURE OF THE THESIS

This document is structured in eight chapters, that show every stage of the process of the research.

In the first chapter it is introduced the statement of the problem, why it needs to be addressed and the objectives of this research.

The second chapter refers to the complete discourse around the topic, like description of issues of city growth, problems related to the use of motorized vehicles, including social, economic and environmental topics, context of where the research takes place like urban structure and climate conditions, as well as the personal approach of this project.

Chapter number three defines the methodology of the research, like information requirements, acquisition of data and analysis, how the proposal is generated and the timetable of activities during the process.

The chapter four describes the case study, defining the limits of the project and the location, a deeper picture of climate conditions in the study area and the current situation of the mobility in the city of Hermosillo, which defines why there is a problem to be addressed.

Chapter number five focuses on the findings from the field work, relating the acquisition of data directly obtained through interviews with stakeholders, observation labor made inside the urban area of the city center, where the project concentrates in, and the data obtained by the implementation of a workshop with a group of volunteers.

In chapter six the analysis of the gathered data is performed, by looking for user needs of the area of study, the necessities and problems that need to be fixed to assure a better accessibility and the requirements limited by climate conditions to promote a more favorable environment to create a more livable, enjoyable and functional urban area, creating a scheme of drafts, drawings and diagrams to analyze all the specific conditions to the climate and to the site.

Chapter number seven shows a design of the interventions proposed for the study area, utilizing the resulting information from the analysis to be applied in the urban structure of downtown Hermosillo, describing its conditions, location of the proposals and the design interventions to generate.

Chapter eight summarizes the entire information, wrapping up the original needs, the requirements founded in place and the analysis made that produced the proposals given to the study area, as well as recommendations for future research on this topic.

CHAPTER II. CONCEPTUAL FRAMEWORK

"Heavy snowfall in the US has repeatedly provided a visual cue into how people behave in transportation. When snow piles up, driving lanes suddenly narrow while leaving more space for parking, pedestrians, or bike lanes. Curved snowbanks create wider pavements, allow pedestrians to spend less time crossing the street and force cars to make slower, saver turns into intersections. Snowy neckdowns illustrate that cars use far less of the road than is allocated to them, thus providing urban planners with arguments for promoting pedestrian-friendly streets. In fact, an intersection in Philadelphia has been redesigned in 2013 by means of traffic patterns after heavy snowfall in winter 2011" (BMZ, 2014)

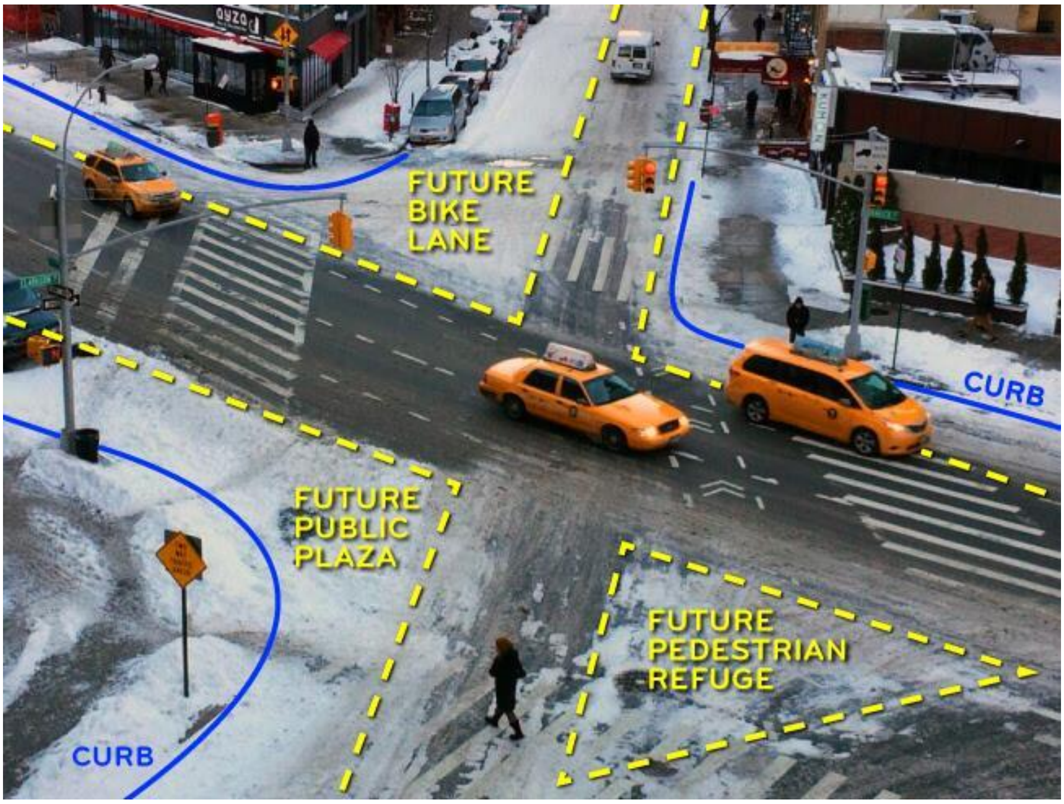


Figure 1. What snow reveals us about streets (Gordon, 2014)

Figure 1 shows how much of a street is really necessary for cars, drawn by neckdowns left from snow, revealing the amount of public space that can be given to other purposes, like pedestrian and biking setups.

According to Tumplin & Millard-Ball (2003) walkability can be maximized when streets accommodate lower volumes of traffic, reducing trips with the benefits of Transit Oriented Development (TOD) when designing the streets, avoiding mistakes like widening roads looking to accommodate more traffic which never arrives or arrives because of the widened streets.

The choice to replace a trip normally made by car to walking, biking or using public transportation is a voluntary action, therefore many cities offer not only improved availability of travel options, but also incentive programs to promote this shift of transit modality. These strategies are programs like bicycle safety education, provision of maps for biking and transit, discounted public transport passes, etc. (Boswell, Greve, & Seale, 2012)

Another incentive program is developed with employers to foment among their employees to choose commuting using alternatives to private motorized vehicles. To encourage the shift to alternative transportation modes needs that walking, cycling and public transportation are more convenient and accessible for every community member. (Boswell et al., 2012)

Figure 2. Bike to work program promoted by Momentum Magazine (Mecklem & Momentum-Mag, 2015)

The Institute for Transportation and Development Policy (ITDP) Mexico declares the need to reduce car use by encouraging shift towards cycling and public transport. Therefore, it has formulated a model city based on four broad areas: a) Cities in which walking and biking is safe, easy and attractive, b) More compact cities in which travel destinations are near and are accessible, c) Cities with fast, comfortable and secure high quality public transport, d) Cities where car travel is the last option. (ITDP México, 2012)

II.1. CITY GROWTH

Le Corbusier published in 1923 his collection called "Towards a New Architecture", where he proposed the general use of rational modern buildings and the creation of functional cities with straight lines, tall buildings, highways and green areas. Many of his ideas were adapted in other publications like the Athens Charter and the Manifesto for Modernistic Urban Planning. These ideas focused on enabling rapid urban growth and the help of cities to function in healthy, safe and effective manners. (Gehl & Svarre, 2013)

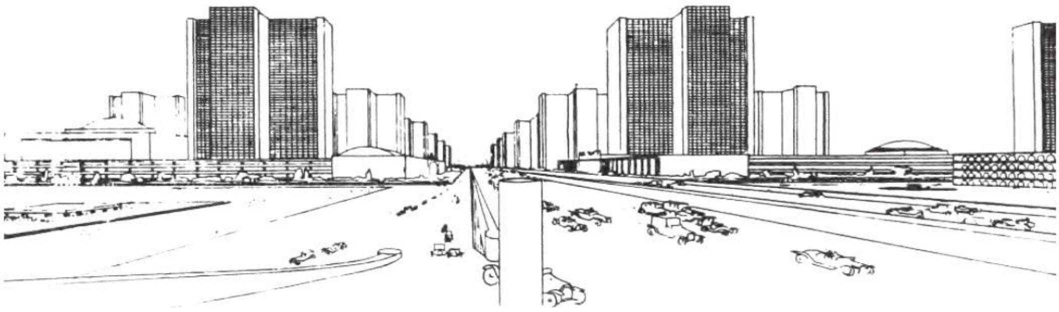


Figure 3. Drawing of Le Corbusier's proposal for a modern city of three million inhabitants, with no fixed location, 1922. (FLC) (MIT-Press, 2013)

Cities have been changing drastically through recent history, for example, 100 years ago there were few cars in cities, nevertheless automobiles began to be part of daily life from 1950, partly because of the economy raise and the cheaper production of cars, making them more affordable for people. In the middle of the 20th century, cities grew rapidly due to an economic development, helping to create an extensive urban expansion and, along with it, the use of automobiles, this caused a more open structure with more space between buildings, beginning an intense growth of cities beyond old boundaries, extending to suburban areas (Gehl & Svarre, 2013)

Whenever there is an extensive growth of a city, causing a low density rate, there is as result a city low in height but large in extension. This provokes places difficult to walk, therefore some other mean of transportation is needed to be able to perform people's daily activities.

"From about the year 2000, it increasingly became taken for granted in the fields of architecture and urban planning practice generally that working with life in cities was crucial. Much bitter experience had shown that vibrant city life does not happen by itself […], less economically viable cities are also impacted, because the rapidly growing volume of motorized traffic and related infrastructure provides obstacles for pedestrians and produces noise and air pollution for many people in their daily lives. The core of the matter is to get the large volumes of life in public spaces to function in a way that allows daily life to take place under decent conditions and partner with the physical framework instead of fighting against it." (Gehl & Svarre, 2013)

"Within the first decade of the 21st century, the world's demographic patterns witnessed a fundamental change. For the first time in history, the number of people living in cities exceeded the number of those living in rural areas. This general trend towards urbanisation has forced policy-makers around the world to quickly find solutions to satisfy the growing demand for transportation services in fastgrowing metropolitan areas—and, in particular, in mega-cities" (Detter, 2015). This movement towards urban areas has been creating extensive growth in cities, producing large trips for daily activities, which usually leads to more difficulties for people with lower economic possibilities, resulting in longer time commuting and higher expenses to pay for traveling to workplaces, which translates in spending less time with their family and for recreation and less money left for nourishment and other activities.

This misfortunate events represent an even worse environment in hot climate cities, due to the necessity of spending more time in the outside, facing harsh conditions like high temperature, in places that, for being "designed" for poor people, tend to have worse settings like lack of good infrastructure, better public places, enough vegetation and even air conditioned spaces for those moments with extreme temperatures.

Commuting patterns are affected by urban compactness. Compact cities are usually determined or measured by residential density, and are associated to shorter travel distances, which can produce shorter travel distances, due to a higher concentration of houses and workplaces. Also a mass transit system can be more competitive thanks to urban compactness. (Ellison, 1995; Veneri, 2009)

According to a publication by OPEC (Organization of the Petroleum Exporting Countries) (Detter, 2015; OPEC, 2015), developing countries there is an impact in energy demand related to transportation needs on growing urban populations […] Fuel consumption increases because of limited public transportation and high congestion of roads, decreasing the efficiency of mega cities.

"In order to accommodate the increased traffic, investments in road infrastructure have been made, leading to an increased number of vehicles on the roads. Furthermore, it could be noticed that due to congestion, the average journey time has increased." (Detter, 2015)

"Addressing congestion problems is often done by making investments in transportation infrastructure. But building infrastructure is costly and can take several decades. Therefore, most measures are considered in the context of the medium to long term. Furthermore, the construction of new roads leads to an increased number of cars." (Detter, 2015)

II.2. ISSUES DUE TO USE OF AUTOMOBILES

The boom in car use has led to an increased need for infrastructure and maintenance of streets, which, with further development and support in the roads, is promoted to continue using such means of transport. All this has caused a vicious cycle that favors the use of the automobile as preferred means of transport on the streets.

“Currently, most of the mega-cities in developing countries rely solely on road transportation since the construction of rail-based public transportation infrastructure is costly and requires a lengthy process for planning and construction. However, road-based transportation leads to a number of problems such as traffic congestion or air pollution. Congestion, in particular, is a major concern for policy-makers since congested roads create opportunity costs and slow economic development.” (Detter, 2015)

The WHO (2016) publishes these list of key facts related to road traffic injuries:

- About 1.25 million people die each year as a result of road traffic crashes.
- Road traffic injuries are the leading cause of death among young people, aged 15–29 years.
- 90% of the world's fatalities on the roads occur in low- and middle-income countries, even though these countries have approximately half of the world's vehicles.
- Half of those dying on the world’s roads are “vulnerable road users”: pedestrians, cyclists and motorcyclists.
- Without action, road traffic crashes are predicted to rise to become the 7th leading cause of death by 2030.

II.2.1. SOCIAL ISSUES

Transport has a great impact on health, and the development of a transport system can either improve health or, on the contrary, increase health risks. The better known risks to health include exposure to air pollutants, noise emissions from motor vehicles and risks of road traffic injuries. A little less known but equally important are the health benefits that can be obtained if the shift includes a certain amount of physical activity such as cycling to get to work or brisk walking (e.g. 15-20 minutes every day) to a public transportation station[1]. (Dora, Hosking, Mudu, & Fletcher, 2011)

[1] Translation from original Spanish made by Hugo Moreno Freydig

Table 1. Health results associated to air pollutants related with transportation. (Dora et al., 2011; WHO, Krzyzanowski, Kuna-Dibbert, & Schneider, 2005)

RESULTS	Pollutants associated in relation with transportation
Mortality	Black smoke, ozone, Particulate Matter ($PM_{2,5}$).
Respiratory diseases (non-allergic)	Black smoke, ozone, nitrogen dioxide, Volatile Organic Compounds (VOCs), Concentrated Ambient Particles (CAPs), diesel exhaust.
Respiratory diseases (allergic)	Ozone, Nitrogen Dioxide, PM, CAPs, Diesel exhaust.
Cardiovascular diseases	Black smoke, CAPs
Cancer	Nitrogen dioxide, diesel exhaust.
Reproductive outcomes	Diesel exhaust, nitrogen dioxide, carbon monoxide, sulfur dioxide, suspended particles

Traffic injuries are also caused by factors such as the use of alcohol, medicinal or hallucinogenic drugs, use of mobile phones, or neglect of personal protective equipment such as helmets (for motorcyclists) or seat belts. Other factors affecting road traffic injuries include environmental design of the street space for pedestrians and cyclists and facilities as well as mechanisms for compliance.[2] (Dora et al., 2011)

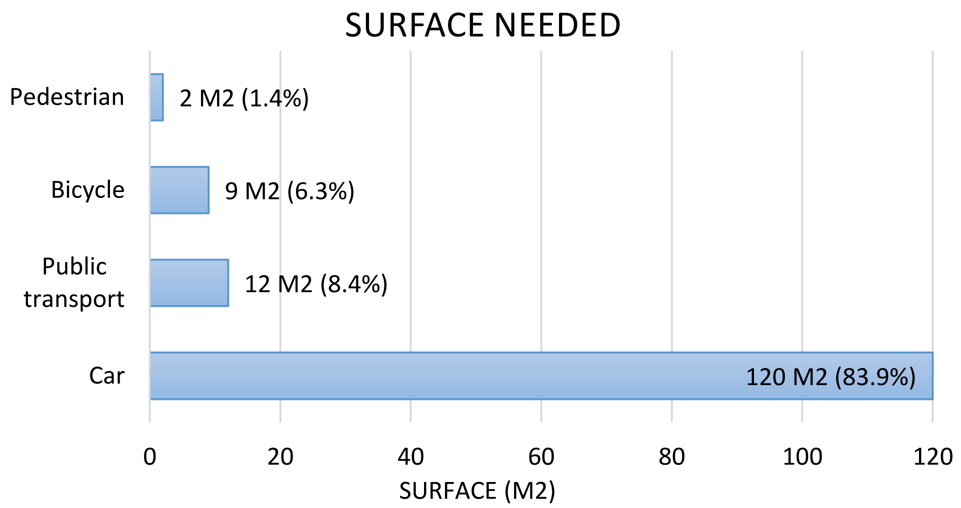
The lack of traffic tends to perpetuate a "vicious circle", which deters many pedestrians and cyclists, while improving road safety can foster a "virtuous circle" that encourages more walking and biking. Acidification traffic measures that lower the engine speed of the vehicles, for example, are associated with increased use of bicycles and walking (Centers for Disease Control and Prevention, 2000; Cervero, 2009). Improve road safety by reducing traffic volumes and speeds are both important ways to help prevent accidents and to encourage healthy physical activity.[3] (Dora et al., 2011)

“In order to truly attract a broad user base, the cycling and walking network must appeal to *choice users* while meeting the needs of those relying on the system out of necessity […] Identifying user needs also requires an understanding of the local culture and associated behaviors […] Understanding where users will be traveling and the routes they are expected to follow is equally important to successful bicycle/pedestrian network development.” (Renfro, 2011)

[2] Translation from original Spanish made by Hugo Moreno Freydig
[3] Translation from original Spanish made by Hugo Moreno Freydig

Table 2. Classification of Transport Costs[4] (Delgado Jalón, Flores Ureba, & Rivero Menéndez, 2014; European-Comission, 1995)

CATEGORY OF COSTS	SOCIAL COSTS	
	INTERNAL OR PRIVATE COSTS	EXTERNAL COSTS
Transport expenses	Costs of oil and vehicles; tolls and price of travel	Costs supported by third-parties (e.g. free parking)
Costs of Infrastructure	Costs concerned to users, taxes on vehicles and fuels	Infrastructure costs not covered
Accident-related costs	Costs covered by insurance, personal costs of accidents	Costs of accidents not covered by insurance (e.g. pain and suffering of third parties)
Environmental costs	Personal bias	Environmental costs not covered by insurance (e.g. third-party discomfort by noise pollution)
Saturation-related costs	Costs of personal time	Costs of delay / time loss caused to third parties



Graph 1. Surface of public space needed by mean of transport. (Urban Transportation Caucus, 2007)

Another issue that can create inequity in the use of public space is the amount of surface needed for every mode of transport, Graph 1 shows the space required by different modes of transport to operate in a proper way, indicating that the private vehicles use a large amount of space, taking into account that the average of travelers per car is 1.2 passengers. (ONU-Hábitat, 2015)

[4] Translation from Spanish version made by Hugo Moreno Freydig

II.2.2. ECONOMIC ISSUES

The costs of transport can be defined as the quantification, in economic terms, of every consumed or sacrificed resources in the events of transportation […] The external costs that transportation imposes include as well increase of traffic congestion, pollution, land occupation, risks of accidents, among others which are also resources consumed within the process.[5] (Delgado Jalón et al., 2014)

These costs are supported by all the population as discomfort or loss of wellbeing, through higher tax payment, or sometimes through transfer to future generations.[6] (Delgado Jalón et al., 2014)

According to Zamorano (2001) and Jimenez *et al* (2011), the main negative externalities of transportation are, among others, urban space occupancy, accidents, destruction and decomposition of urban space, atmospheric pollution, noise and traffic congestions.[7]

"An increasing number of road accidents not only means a considerable loss of human lives but also important economic costs to society. According to the Transport Research Laboratory (TRL) figures, traffic accidents annually cost developing countries around US $53 billion […] traffic safety remains an important public and social priority issue as well as an economic challenge." (García-Ferrer, De Juan, & Poncela, 2007)

According to Speck (2012) one solution to excessive driving and congestion is the so called "congestion pricing" in which case motorists are asked to pay something closer to the real cost of driving. This allows people to make market-based choices about when and where to drive. He also describes the example of London in early 2000s, where the city was clogged with traffic, and people were desperate for a solution, in which case Mayor Ken Livingstone proposed to apply a fee, equivalent to $ 15 US Dollars, for any driver who wanted to enter the city center on weekdays. With this strategy congestion dropped by 30% inside the toll zone, journey times decreased 14%, cycling in London increased 20% and air pollution went down about 20%. The revenue, equivalent to over 1 billion US Dollars, was invested in mass transit.

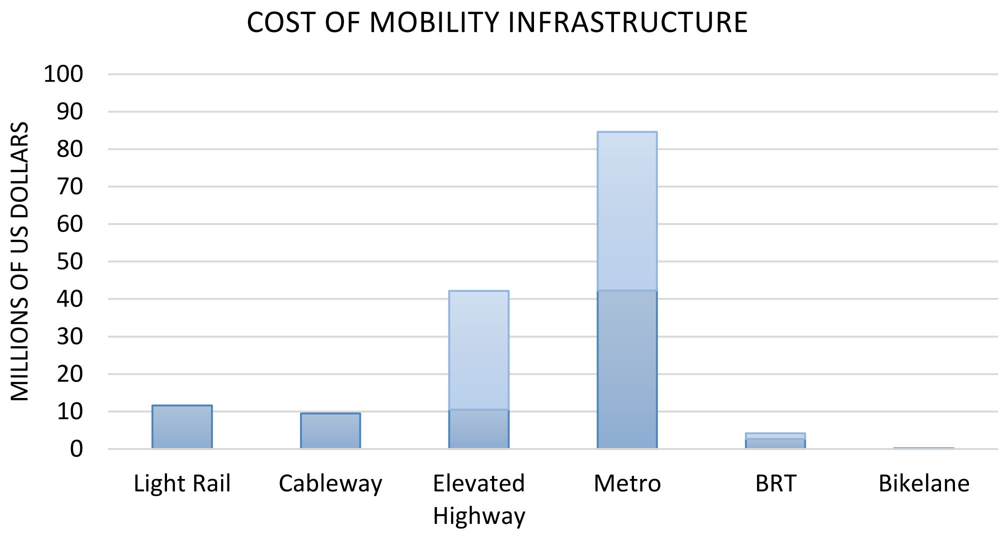
Table 3. Effective speed of different vehicles and annual costs per person[8] (Tranter, 2004)

	Average car	**Public Transit**	**Bicycle**
Annual vehicle costs	$ 2,852 USD	$ 734 USD	$ 380 USD
Effective speed (km/hr)	18.1	21.3	18.1

[5] Translation from original Spanish made by Hugo Moreno Freydig
[6] Translation from original Spanish made by Hugo Moreno Freydig
[7] Translation from original Spanish made by Hugo Moreno Freydig
[8] Conversion from original Australian Dollar to US Dollar. Currency rate 23. june.16

Table 3 displays a comparison between different means of transportation, showing the amount of expenses derived by each method, as well as the effective speed of each in an urban environment. One can notice the high quantity of cost that average car traveling represents compared with the lower cost of using public transportation and riding a bike. Likewise, the data shows a higher speed rate that the use of public transit provides against car or bicycle ride. (Guidebook & Litman, 2011; Tranter, 2004)

According to ITDP Mexico (2013) there is a high difference of cost of implementation between several means of transportation (see Graph 2). They also present the cost of construction for sidewalks, which is 25.37 US Dollars per square meter, and bike sharing with 2,500 US Dollars per unit. This means that the most economic methods of urban transport are walking, cycling and the BRT system.



Graph 2. Cost of implementation of different means of urban transport (ITDP México, 2013)

"Transit Oriented Development can provide economic benefits by improving accessibility, reducing transport costs […] Increased property values near transit stations can offset most or all transit subsidy costs (CTOD, 2010; RICS, 2002; Smith & Gihring, 2004). Even people who do not use transit can benefit from these land use patterns." (Tranter, 2004)

II.2.3. ENVIRONMENTAL ISSUES

"Cities are dynamic and unique and these are projected to undergo unprecedented change due to a combination of global and local challenges associated with factors such as population growth, increasing urbanization, patterns of migration, climate change and increasing energy demand (Kumar et al., 2014, 2015). One of the currently facing challenges of the cities are heat waves, which have been becoming more frequent since the mid-20th century (IPCC, 2007), leading to human thermal discomfort and severe medical cases, such as heat strokes and cardiovascular problems. As a result, mortality rate has increased. An example of this is excess mortality of ~35,000 that was noted during the heat wave event in August 2003 in Europe. Apart from the adverse effects on human health, thermal discomfort leads to an increase in the demand for air conditioning and, in turn, in the energy consumption and production of greenhouse gases (Kumar & Morawska, 2013). Therefore, there is an urging need for urban design and planning to respond with appropriate pre-cautionary measures that take into consideration urban microclimate and the mitigation of the urban heat island (UHI)." (Kakoniti, Georgiou, Marakkos, Kumar, & Neophytou, 2016)

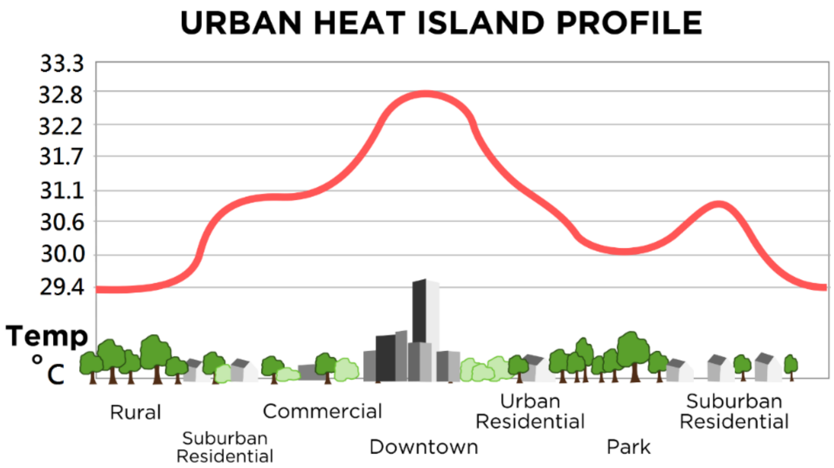


Figure 4. Urban Heat Island Effect. (Wikimedia Commons, 2011)

The UHI (see figure 4) effect occurs when urban areas get warmer than their rural surroundings. Cities are more susceptible to experience higher air temperatures caused by their increased heat capacity due to anthropogenic heat sources and impervious urban surfaces, which inhibits evaporative cooling. (Lauwaet et al., 2016)

The increased temperature in cities is not the only issue caused urban growth, another problem is the excess emissions of Carbon Dioxide, which increases the possibilities of having health and environmental alterations.

"The transportation sector is a major source of CO2 emissions and currently contributes 20-25% of global CO2 emissions. Its global share is projected to rise to 30-50% by 2050 (Brand, Goodman, Rutter, Song, & Ogilvie, 2013). It is estimated that the most targeted measure to reduce GHG emissions in an urban development context should be aimed at reducing transportation CO2 emissions (Norman, MacLean, & Kennedy, 2006)." (Yuanqing Wang, Yang, & Han, 2016)

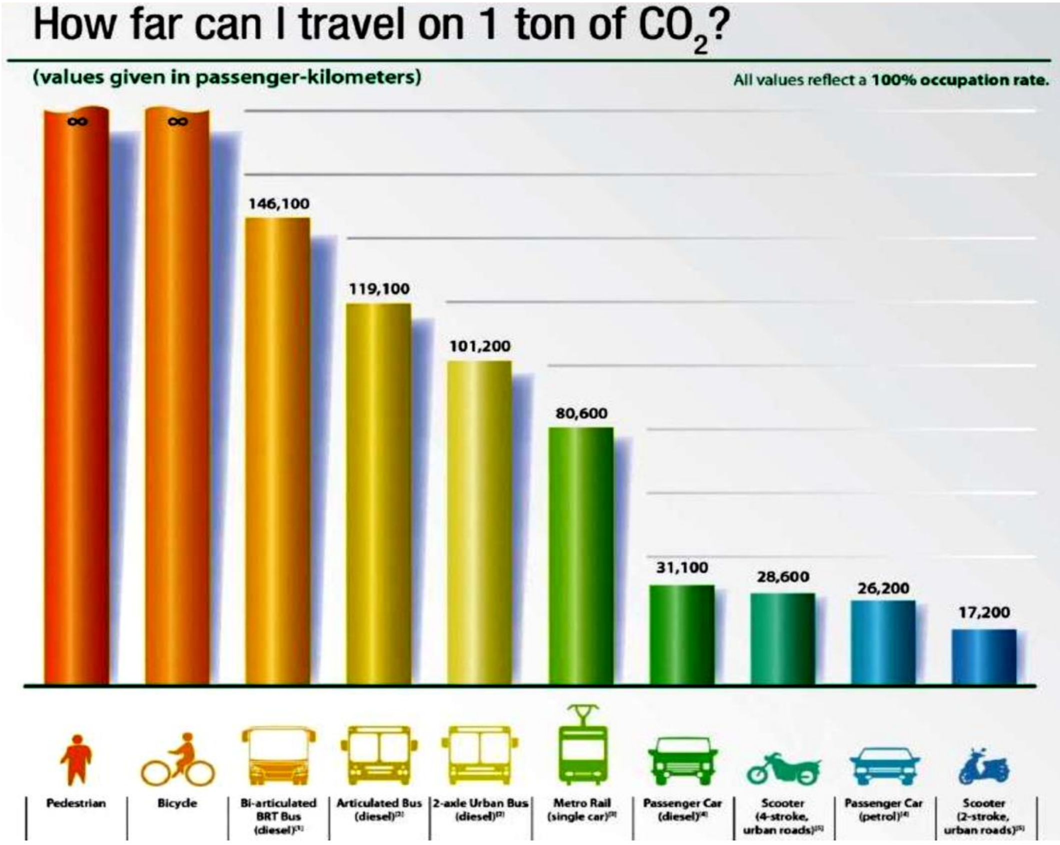


Figure 5. Possible mileage by transport mean with 1ton of CO2 (Ecobici, 2012; Sarabia, 2013)

Figure 5, published by the Ecobici program of the City of Mexico, with data from the German Society for International Cooperation (GIZ), illustrating a study in which the amount of distance that can be covered with different means of transport are compared, having as limit the emission of one ton of CO2. It is noted that the pedestrian and bicycle path maintain an infinite zero-emission, up to cars and motorcycles, which emit as much carbon dioxide per kilometer.

Table 4. Per passenger per kilometer CO2 emissions by means of transport. (Amici della Terra, 2005; Veneri, 2009)

Means of Transport	Gr CO_2/pkm
Train	*35*
Tram	*32*
Underground (Metro)	*21.3*
Urban bus	*72*
Extra-Urban bus	*26*
School or company bus	*31*
Car	*105*
Motorbike	*80*
Bike, on foot, other	*0*

In comparison, table 4 presents the amount of CO2 emissions generated by different methods of transportation, being able to notice that private vehicles are the most inefficient transit means, presenting a much lower amount of Carbon Dioxide emissions the public transportation systems like bus and rail-based systems and, of course, walking and cycling, whose CO2 emissions are null.

II.3. CONDITIONS REGARDING PLACES WITH WARM CLIMATE

Renfro (2011) presents the case of Liwa, Mirfa and Ruwais, in the Arabian Desert, where the weather conditions create a different environment, compared to other cities where water-intensive features are used to enhance the streetscape environment, providing thermal comfort, nevertheless in desert locations water must be used carefully. Taking in consideration physical orientation, width of future streets, sun patterns and prevailing winds. The author also affirms that shading with taller building façades next to sidewalks and the use of local materials needs to be implemented. Besides those described, integration between pedestrian, bicycle and transit infrastructure has to be created, providing elements like shelters, posted maps, schedules and rider information, as well as facilities for bicyclists like parking and showers and changing facilities at workplaces.

Flynn et al (2012) suggests that there is relation between bicycle use and weather conditions, nevertheless there is a lack of information about the influence on bike use behavior (Heinen, Van Wee, & Maat, 2010; Saneinejad, Kennedy, & Roorda, 2010), and the information founded most of the times refer to cold weather and places with plenty of rainy days, presumably because these papers are usually produced in cities from Europe or the US.

“Outdoor natural environment can produce either positive or negative influences on individual’s physical activity levels. Natural environments are more exposed to uncontrollable extreme weather conditions which may induce discomfort or even may pose health threats. Inclement weather with hot and cold seasons lowered the participation rate, frequency and duration of physical activity (Spinney & Millward, 2011)” (Y. Wang, Chau, Ng, & Leung, 2016)

A research made in Phoenix, Az., USA. and Marrakesh, North Africa, demonstrated that in hot arid climates there is an influence on people’s behavior on the way they use open spaces according to weather conditions. It was found that, when the intensity of solar radiation decreases, people tend to spend more time outdoors. The authors also proclaim that design is an important parameter, which can improve the conditions of a place’s microclimate, therefore it is important to create an adequate design of outdoor spaces in hot climate zones, in a way that they can host different activities and stimulate people to visit those spaces and stay longer. (Aljawabra & Nikolopoulou, 2010).

Nakayama and Fujita (Nakayama & Fujita, 2010) affirm that the UHI effect is caused when the urban temperature is higher than their rural surroundings, being a serious environmental problem due to the large amount of covered surfaces with concrete or asphalt. These materials can concentrate a high level of temperature during the day, releasing it into the atmosphere at night. Water surfaces and open parks are essential in urban areas, in order to generate an urban cool-island (Chang, Li, & Chang, 2007; Spronken-Smith & Oke, 1999)

Alongside with the diminished absorption of solar radiation by the use of impervious materials (Melaas, Wang, Miller, & Friedl, 2016), the plantation of vegetation in the cities which is not endemic or adapted to the climate and environmental conditions of the region can produce alterations of ecosystem's behavior, like pollination and plagues. Likewise, plants may require different amounts of irrigation, therefore they should be located according to their water needs. (Duffield & Jones, 1992)

Besides the environmental alteration, human behavior tends to be adjusted according to the weather conditions, for instance the way people conduct when coping with high temperatures and high solar radiation.

"Building the non-motorized transportation system is important, but strategies beyond infrastructure improvements are needed for bicycling and walking to truly become *everyday* travel modes." (Renfro, 2011)

II.4. TRANSIT ORIENTED DEVELOPMENT

"Transit-Oriented Development is regional planning, city revitalization, suburban renewal, and walkable neighborhoods rolled into one. It is a cross-cutting approach to development that can do more than help diversify our transportation system; it also offers a new range of development patterns for households, businesses, towns, and cities […] TODs are never stand-alone. They must be conceived in the context of, at the very least, a corridor and a metropolitan region. They are an alternative that provides choice not only in transportation mode but, more fundamentally, in lifestyle." (Calthorpe, 2011)

TOD is an urban model with design and planning around public transport, constituted by compact neighborhoods, with high density, that allows people to enjoy a diversity of use, services and safe and active public spaces, in favor of social interaction. It is an integrate strategy that gives solutions to local and regional mobility, satisfying most of the needs of its inhabitants in a pedestrian or bicyclist manner, connecting to the rest of the city or region though good quality public transportation. This reduces to a minimum dependency of automobiles[9]. (CTS-Embarq, 2009)

[9] Translation from original Spanish made by Hugo Moreno Freydig

Table 5. Key elements of TOD (CTS-Embarq, 2009)

- Non-motorized mobility
- High-quality public transportation
- Safe and active public spaces
- Mix-use land
- Active ground floors
- Management of automobiles and parking
- Community participation and security

This project concentrates on the research of the first element "*non-motorized mobility*", with a primary focus on adaptation to hot-climate cities.

The TOD design gives a hierarchy of the public space on the following manner:

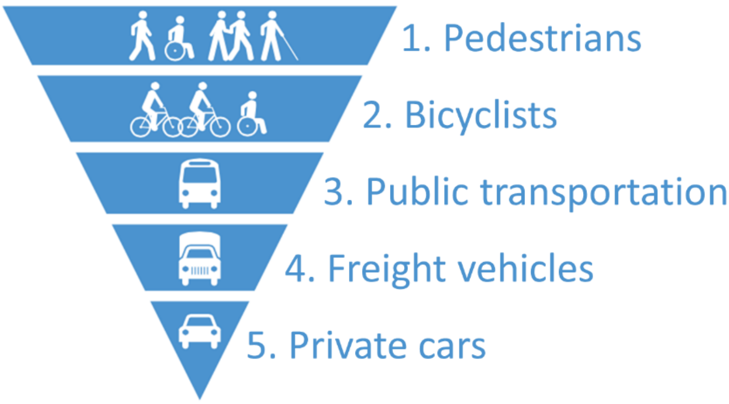


Figure 6. Pyramid of Mobility: Hierarchy of the streets. Source: Adaptation from Ilustre Municipalidad de Santiago (2015)

"Unlike road systems, transit should be conceived hierarchically: from walkable and bikeable streets supporting local bus and streetcar lines to trunk transit lines with dedicated rights-of-way. This hierarchy is essential to transit's success. Leave out any element and the system becomes inefficient and inconvenient, resulting in what we now have: transit systems that need more subsidies than necessary and cannot attract a growing ridership". (Calthorpe, 2011)

II.5. EXPERT'S RECOMMENDATIONS

Along with the TOD guides published by international institutions like Embarq (2009) and ITDP (2014), there are nowadays a few worldwide known city planners that have been helping to create better cities, developing their own approaches to solve common issues in the cities. Some of these authors and their ideas are described below.

II.5.1. JEFF SPECK

Jeff Speck is a city planner and urban designer from the US, he has been advocating for smart growth and sustainable design through his built work, lectures and writing. He has published a book titled: "Walkable City: How Downtown Can Save America, One Step at a Time" (Speck, 2012) where he lists 'the ten steps for walkability' and some quotes from every step:

- **The Useful Walk**
    1. **Put Cars in Their Place:** "Induced demand is the name for what happens when increasing the supply of roadways lowers the time cost of driving, causing more people to drive and obliterating any reductions in congestion". "The key is to welcome cars in the proper number and at the proper speed". "Walkable cities, with their dense, vibrant, mixed-use neighborhoods, offer residents a lifestyle that combines superior economic and social opportunity with a transportation cost, in both time and money, that is not necessarily any higher […]".
    2. **Mix the Uses:** "Cities were created to bring things together. The better they do this job, the more successful they become". "What do humans do? Work, shop, eat, drink, learn, recreate, convene, worship, heal, visit, celebrate, sleep: these are all the activities that people should not have to leave downtown to accomplish".
    3. **Get the Parking Right:** "The first step to understanding how parking works is to get a grasp of how much it costs and who pays for it. Because it is so plentiful and often free to use, it is easy to imagine that it costs very little. But this is not the case". "The destruction of architectural masterpieces is one of the most obvious and upsetting manifestations of modern parking pressures".
    4. **Let Transit Work:** "Every transit trip begins and ends with a walk. As a result, while walkability benefits from good transit, good transit relies absolutely on walkability". These conditions are what is lacking in much of transit today: *Urbanity* means locating all significant stops right in the heart of the action […] *Clarity* means a route that is a simple line or loop, with as few diversions as possible. This not only expedites travel -and limits frustration- but also allows riders to form a mental image of the path, so important to their comfort […] *Frequency* is the thing that most transit service gets wrong. People hate to look at schedules almost as much as they hate waiting, so ten-minute headways are the standard for any line that hopes to attract crowd […] GPS-enabled time-to-arrival clocks at stations (and smartphone apps) are also essential, and particularly helpful after hours […] *Pleasure* is the mandate that is most often

overlooked by transit officials, yet the search for its attainment is at the heart of so many human choices […] The imperative of competitive transit has a hard side and a soft side. The hard side is about not wasting people's time and the soft side is about making them happy. If you can commit to doing both, then you can get people out of their cars".

- **The Safe Walk**

5. **Protect the Pedestrian:** "The cities with the smallest blocks are the ones best known for walkability, while those with the largest blocks are known as places without street life". "The safest roads are those that feel the least safe, demanding more attention from drivers". "If your downtown lacks vitality and it's got one-ways, it's probably time for a change". "What makes a sidewalk safe is not its width, but whether it is protected by a line of parked cars that form a barrier of steel between the pedestrian and the roadway". "Would most intersections be safer with one traffic signal rather than twelve? Maybe, maybe not. But many streets would be safer with four-way stops signs. And we could sure use the savings".
6. **Welcome Bikes:** "New York City recently saw a 35 percent jump in ridership in one year alone, thanks specifically to its strong commitment to an ever-improving bicycle network". "As bike lanes have been added along New York's avenues, injuries to pedestrians have dropped by about a third". "Compared to the car, the bicycle's special demands are minimal. Ten bikes can park in the space of a single car, and the typical bike lane handles five to ten times more traffic volume of a car lane twice its width". "The goal of an intelligent cycling plan should be to allow bikes access to every address in the city. Some of those trips will be on separated paths, others on bike lanes, and most will be mixing traffic on slower streets […] The dream is to get bicyclists where they need to go".

- **The Comfortable Walk**

7. **Shape the Spaces:** "People need to be spatially contained by the walls of buildings. Most of us enjoy open spaces, long views, and the great outdoors. But we also enjoy -and need- a sense of enclosure to feel comfortable as pedestrians". "Many cities actively work against spatial definition with the requirement for shadow studies, which are often used to chop the tops off tall buildings in urban centers. These make sense against public greens and in dark, northern cities like Boston, where light and air are at a premium, but what are they doing in Miami Beach, where shadows are what make summer walking possible? Where they are necessary, shadow studies need to be supplemented by "shaping studies" that show how well buildings make streets into spaces". "There is no doubt that climate exerts some influence on walking, but the evidence suggests that this factor is not half as impactful as street design". **"Get the design right and people will walk in almost any climate"**.
8. **Plant Trees:** "Street trees are key to pedestrian comfort and urban livability in so many ways. In addition to offering shade, they reduce ambient temperatures in hot weather, absorb rainwater and tailpipe emissions, provide UV protection, and limit the effects of wind". "Because they have such a powerful impact on walkability, street trees have been associated with significant improvements in both property values and retail viability".

"A properly shaded neighborhood is said to require 15 to 35 percent less air conditioning than a treeless one".

- **The Interesting Walk**

9. **Make Friendly and Unique Faces:** "We demand almost constant stimulation. Pedestrians need to feel safe and comfortable, but they also need to be entertained, or else those with a choice will choose to drive. And what could be more boring than a parking lot?". "What matters even more is getting the scale of buildings right, so that each block contains as many different buildings as reasonably possible. Only in this way will the pedestrian be rewarded with the continuously unfolding panorama that comes from many hands at work".
10. **Pick Your Winners:** "The previous nine steps embody a comprehensive strategy for creating walkable places […] following all steps, rather than just a few of them, is essential if we are to convert a large segment of drivers into walkers. But following these steps everywhere would bankrupt most cities". "The first question to ask before investing in walkability: where can we spending the least money make the most difference? […] Places where an accommodating private realm already exists to give comfort and interest to an improved public realm. Most cities have their fair share of streets like this, where historic shopfronts and other attractive buildings line sidewalks that are blighter only by a high-speed, treeless roadway. **Fix the street, and you've got the whole package, or close to it**".

"The downtown is the only part of the city that belongs to everybody It doesn't matter where you may find your home; the downtown is yours, too. Investing in the downtown of a city is the only place-based way to benefit all of its citizens at once". (Speck, 2012)

II.5.2. JAN GEHL

"Jan is an Architect, Founding Partner of Gehl Architects, and former Professor and Researcher at The Royal Danish Academy of Fine Arts, School of Architecture. Over the course of his career, he has published several books, including, "Life Between Buildings", "Cities for People", "New City Spaces", "Public Spaces – Public Life", "New City Life" and most recently "How to Study Public Life". As part of Gehl, Jan has collaborated on projects for the cities of Copenhagen, London, Melbourne, Sydney, New York and Moscow, among others". (Gehl, 2013)

Jan Gehl, as part of his book *How to Study Public Life* (Gehl & Svarre, 2013) presents a chart with a list of keywords for urban design. Within this set of keywords, highlights a group of them called "The 12 Quality Criteria" (narrowed down from an original list of 43 elements, made in 1974), which is a check-list to assess public space qualities. The main set of 12 are the following (numbering contains four gaps, intentionally left out by Jan Gehl):

1. **Protection against traffic and accidents**
   - Traffic accidents
   - Fear of traffic
   - Other accidents
2. **Protection against crime and violence**
   - Lived in
   - Street life
   - Street watchers
   - Social structure and identity
   - Overlapping/cohesion
   - In space and time
   - Lighting (when dark)
3. **Protection against unpleasant sense-experiences**
   - Noise
   - Smog
   - Stench – smell
   - Dirt – dust
   - Blinding
5. **Possibilities for walking**
   - Space for waking (dimensions)
   - Lines of walk (organized)
   - Distance of walk (m / feet)
   - Distance of walk (experienced)
   - Surface (Materials)
   - Surface conditions (snow, etc.)
   - Change of level
6. **Possibilities for standing**
   - Standing zones
   - Standing spots
   - Support for standing
7. **Possibilities for sitting**
   - Zones for sitting maximizing advantages
   - Primary sitting possibility
   - Secondary sitting possibility
   - Benches for resting
8. **Possibilities to see**
   - Seeing – distances unhindered lines of vision
   - Views
   - Lighting (when dark)
9. **Possibilities for hearing/talking**

- Noise level
- Talking distances
- Bench arrangements

10. Possibilities for play/unwinding
- Play
- Dance
- Music
- Theatre
- Soapbox speeches.
- Different age groups
- Different people

14. Small scale services (friendly gestures)
- Signs
- Telephone booths
- Post boxes
- Notice boards
- Maps of town
- Pushcarts / baby carts
- Waste paper baskets

15. Design for enjoying positive climate elements
- Sun
- Warmth / coolness
- Breeze / ventilation

16. Designing for positive sense experiences
- Aesthetic qualities
- Views
- Nature, plants, trees, flowers, animals

II.5.3. JANNETE SADIK-KAHN

Born in San Francisco, California, USA, Sadik-Kahn works as Commissioner of the New York City Department of Transportation. She has implemented programs to improve safety, mobility and sustainability mainly in New York. She is President of the National Association of City Transportation Officials (NACTO) (IMDb, 2014). She has published the book “Streetfight: Handbook for an Urban Revolution” (Sadik-Khan & Solomonow, 2016), from where these set of quotes were obtained:

> “Transforming a car-clogged street into inviting shared space doesn’t always require heavy machinery, complicated reconstruction, or millions of dollars. Planners can reorder a street without destroying a single building, double-decking a street, or building a streetcar, light rail system, or highway interchange. It can be accomplished

quickly by using the basic materials that every city has access to—in New York City's case more than six thousand miles of streets—and the basic stock that all city transportation agencies already have in their supply depots or available through existing contracts. Yes, I mean paint. Hundreds".

"The fast implementation of projects proved to be far more effective than the traditional model of attempting to achieve near unanimity on projects even when you already have consensus that the status quo doesn't work. Efforts to reach an idealized consensus have resulted in years of indecision, inaction, and paralysis by analysis as leaders attempt to placate the opposition that accompanies any charge to streets".

"A city whose streets invite people to walk, bike and sit along them also inspires people to innovate, invest, and stay for good".

"Real-world experience showed that reducing the number of lanes on carefully selected streets or closing them entirely not only provided pedestrian space and breathed new life into neighborhoods, but also actually improved traffic. Simply painting part of a street to make it into a plaza, bike, or bus lane not only made the street safer, it also improved traffic and increased bike and pedestrian foot traffic and helped local businessman to prosper".

"Cities' geographic compactness, population density, and orientation toward walking and public transportation make them the most efficient places to live in the world".

"As long as planners widen roads and build new ones; as long as drivers have poor transportation options and remain insulated from the full cost of their trips; and as long as government policies encourage people to live in far-flung suburbs, we will have an even more sprawling urban future".

"If you're inducing demand, make sure it's the right demand: More bike infrastructure=more bike riders". (Sadik-Khan, 2016)

II.6. APPROACH

The seven key elements of Transit Oriented Design, described in table 5, are combined to create better conditions for living and enjoying the public space, and define a way to integrate the components of the urban environment.

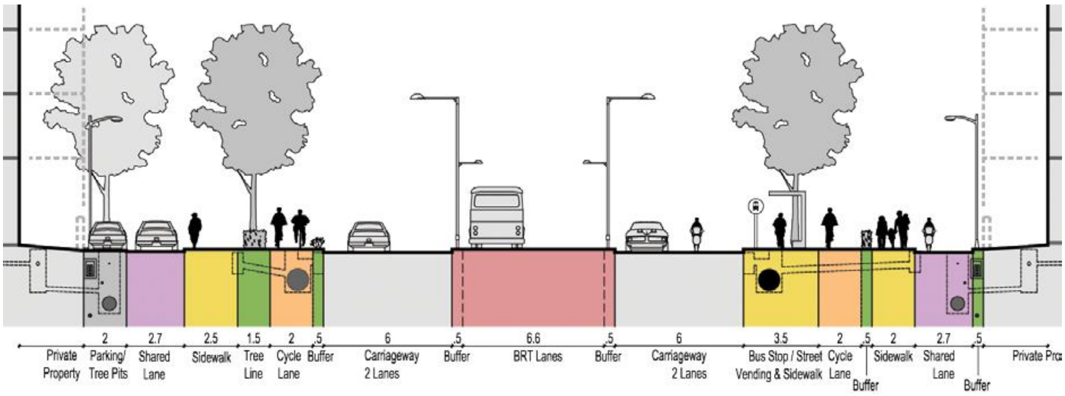


Figure 7. Template of streets with Bus Rapid Transit: "42BRT c" (ITDP & EPC, 2011)

Originated from these principles, several organizations have created their own approach to the design of TOD streetscapes (see example in figure 7), nevertheless they are usually developed as proposals for locations that have milder climate conditions, where people are able to enjoy the public space regardless of special considerations of weather problematics.

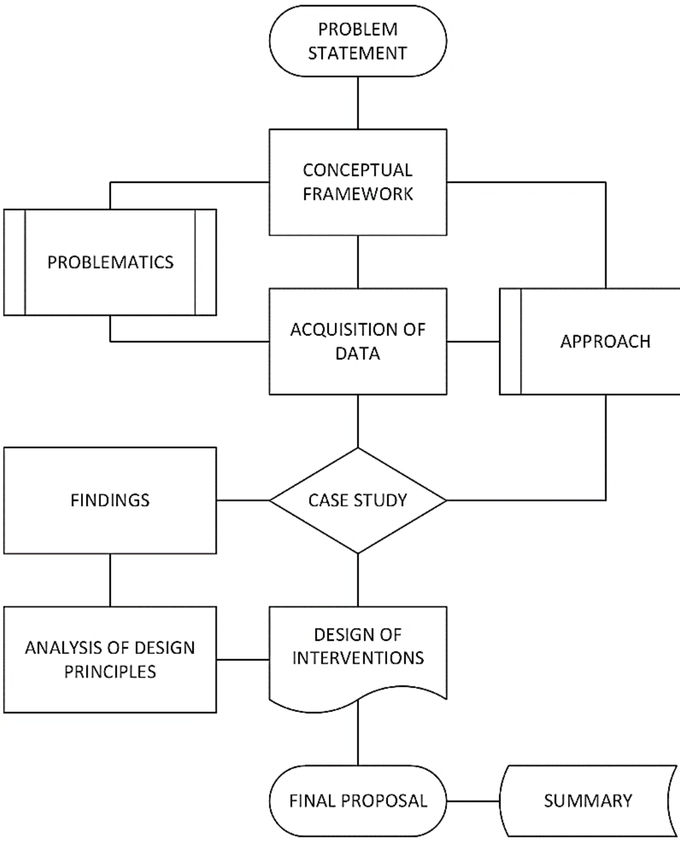


Figure 8. Flowchart of structure of thesis

This is specially the case for pedestrians and bicyclists (components of non-motorized mobility), because they are the most vulnerable users of the street (see figure

8). They are bare not only confronting the iron shells that cover motorized users, but also against the atmospheric conditions.

This is why this work seeks to generate a design plan that is created analyzing the specific circumstances like temperature, insolation, humidity levels, wind, orientation and location, as well as urban furniture, transit requirements, vegetation, hardscape, construction materials and shading needs that hot climate cities present, focusing in non-motorized mobility, utilizing the case study of downtown Hermosillo, Mexico to exemplify the particular design interventions needed to perform to promote Transit Oriented Development in warm climate cities, in order to produce more habitable urban environments where using non-motorized modes of transportation represent an efficient and attractive alternative, helping to reduce the use of automobiles, along with its externalities.

CHAPTER III. **METHODOLOGY**

In order to achieve a more integrated approach to this proposal, a series of processes that go from the statement of the problem, to the design of the proposal. These require a research of theoretical concepts, the analysis of the general problematics founded, the selection of the design strategies to implement and the design of the interventions to propose, according to the specific characteristics of the case of study.

The main topic of the thesis is the design of a scheme for urban mobility in warm climate cities, with a specific focus on pedestrian and cycling facilities and infrastructure. The emphasis in walking and pedaling is because these modes of transit help to improve conditions for commuting throughout the city in a more environmental friendly manner, due to the lack of pollutants, CO2 and other toxic emissions that motorized vehicles produce, as well as improving the transit on the streets.

Due to the specific settings founded in warm climate cities, the research will look to generate better conditions in these urban environments, to be able to walk, cycle and use public transit systems despite the presence of high temperatures and other weather-related difficulties that may affect people’s performance in public spaces.

III.1. DATA NEEDS

As part of the conceptual framework, a research as introduction of the general problematics was performed, revising information about TOD standards, a broad idea about warm climate cities and its difficulties, as well as the behavior response of people through those characteristics and finally a first glance about the place where the research would be implemented.

Later on, bibliographic research about issues of city growth, the downside of motorized vehicle transportation, and how urban structure faces climate conditions was made.

As part of the information to be gathered in place, on the site of case study some information regarding the zone to work with, the current projects and proposals and from the municipality department in charge of urban planning was compiled. Personal observation was made, gathering photographic evidence and doing annotations regarding land use in the study area. Along to those, a workshop was implemented, with a group of volunteers, applying three techniques to collect information and receive feedback.

Then, a series of design principles were chosen and tested through software analysis to assure their feasibility of implementation and coping with the local climate conditions and global position, addressing insolation, taking into account the sun path and people's necessities, creating a series of drafts and diagrams, later to be applied using the actual site information before compiled.

Once all the relevant information was obtained, the proposal was produced, considering the objectives to achieve, the conditions founded and the main goal of the research. This proposal consists in a scheme of blueprints, 3D renderings and photomontages, looking to generate a mobility plan that tries to improve the use and distribution of public space and the connectivity with the rest of the city.

III.2. ACQUISITION OF DATA

Within the bibliographic research, information was compiled about the way that cities have been growing around the use of cars, exploring issues that have been originated from its use. Besides, it was characterized the general urban conditions presented in cities with warm climate. At the same time, information published by INEGI regarding mobility in Hermosillo has been taken into account.

As part of the solutions approach, an overview of Transit Oriented Development was made, describing the elements that constitute it, as well as information about the main focus of the thesis, pedestrians and bicyclists (non-motorized mobility).

III.2.1. CHARACTERIZATION OF IN-SITE RESEARCH

Regarding the case study, a series of data from the site and its weather conditions have been collected, helping to give an outline of the area to work with and the situations to cope to.

The first exercise consisted in an exploratory visit to the area to analyze, which consisted in doing a tour in every one of the streets inside the case study zone (to be described in the next chapter) to check the actual use of the land and compare against the official map of land use provided by IMPLAN Hermosillo, as well as creating an image bank with photos from the most representative streets and public spaces from the study area.

Besides the observation phase, a couple of semi-structured interviews (Barriball & While, 1994; Newton, 2010; Paine, 2007) were made; these helped to get evidence of the topics related to the project, while allowing the interviewee to express himself/herself, thanks to the more open structure of the interview, allowing at the same time to adjust and add more questions according to the information received.

For the interviews, stakeholders were chosen according to their involvement in the planning of the study area. These were, on the one hand, the Director and the President of the "*Patronato Pro Obras del Centro Cívico y Comercial de Hermosillo, AC.*" (Pro-works Patronage of the Civic and Commercial Center of Hermosillo), and the

Director of "*Instituto Municipal de Planeación Urbana de Hermosillo*" (Municipal Institute of Urban Planning of Hermosillo), also known as IMPLAN, where I was able to obtain information about their current and future plans for urban development and mobility in the study area.

As well as the interviews, a workshop with the topic 'mobility' was made, combining three methods of obtaining information: Photovoice, a tour for obstacles finding and a proposals training. Originally the workshop was intended to be performed with a group of merchants from the downtown area, the Patronage was supposed to be the link between the merchants and myself, nevertheless the communication to the Patronage was broken, therefore I decided to do the workshop independently, with users and costumers of the city center, instead of the merchants. The workshop was made with a group of five architects, where they were able to share their insights regarding the mobility situation in the area of study. As inhabitants of Hermosillo and users of the downtown shopping area they gave suggestions and talked about the problematics they have experienced when being in the city center.

Photovoice is participatory action research strategy that works as a methodology that combines photography, critical dialogue and experimental knowledge (Sutton-Brown, 2014). The steps for conducting the study proposed by Wang (1999) are the following:

1. Select and recruit a target audience of policy makers or community leaders.
    - The chosen stakeholders are the Director of IMPLAN Hermosillo and the President and Director of the Pro-Works Patronage of the Historical and Civic Center of Hermosillo, for being the Institutes responsible of improving the urban conditions of the area of study.
2. Recruit a group of Photovoice participants.
    - The workshop was made on June 4th, 2016, where a group of volunteers was gathered. An open call was made via Facebook, Twitter and through personal communication.
    - It took place at the architecture school of the University of Sonora, where a lecture room kindly was provided by the Chief of the Department of Architecture and Design.
3. Introduce the Photovoice methodology to participants and facilitate a group discussion.
    - The Photovoice methodology, as well as the obstacles finding tour and the proposals training was introduced prior to the beginning of the walk around the city center.
4. Obtain informed consent.
    - The photographs were taking principally accessibility issues on the streets and sidewalks, this means difficulties for people to use the space, like lack of ramps, existence of holes or bumps in the pavement and obstacles founded in the way that could be harmful for people with disabilities or any kind of pedestrians. The pictures did not intend any harm to the people that were

occasionally in the photographed scene, nor the cameras were hidden for snapping unauthorized photos.

5. Pose an initial theme for taking pictures.
    - The theme for the pictures taking was "mobility obstacles and opportunities", and it was asked to the participants to have in mind the following aspects:
        - Land use of the zone (commercial, housing, equipment, mix).
        - Spaces for pedestrians, cyclists, public transport.
        - Sizes and conditions of sidewalks.
        - Sunny and shaded areas.
        - Viability of pedestrianization of streets.
        - Viability of changes to public transportation routes.
        - Viability of changing some street's direction.
        - See potential of public space: Think ahead.
6. Distribute cameras to participants and review how to use them.
    - Participants were asked to use their own smartphones to take pictures. All of them kindly agreed to use their own devices for the proposes of the exercise.
7. Provide time for participants to take pictures.
    - The exploratory tour lasted around 1.5 hours. During that time the participants were able to take pictures of their own findings, doing stops every time it was needed or asked.
8. Meet to discuss photographs.
    - After the tour, I asked the participants to upload their photographs to the event posted on Facebook, where they were asked to give a caption to their pictures.
9. Plan with participants a format to share photographs and stories with policy makers or community leaders.
    - The photographs, as well as all the information they provided as their ideas, opinions and proposals, were shared via Facebook, some of them are taken to be part of this thesis, which will be presented to IMPLAN Hermosillo and the Pro-Works Patronage of the Historical and Civic Center of Hermosillo.

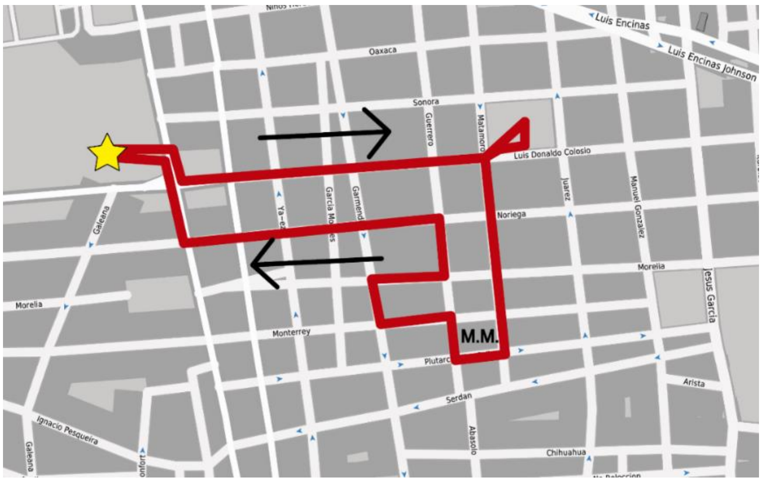


Figure 9. Map of the exploratory tour around the city center. (Made with Open Street Maps information)

Figure 9 shows the path that was walked during the exploratory tour of around 1.6 km, visiting some of the most iconic streets and venues of downtown Hermosillo.

Figure 10. Obstacle finding kit (Mansilla, 2016a)

Along with the Photovoice exercise, during the tour a second method was used, where we had an “Obstacle finding kit” and a method called *“Mira dónde pisas”* (watch your step), as proposed by Verónica Mansilla (2016a, 2016b), both presented on the 3rd. Congress for Pedestrians in Mexico City. The device (see figure 10) was replicated, made with a cord, a cap of a PET bottle, a chalk located 75 cm away from the center of the cap and a sticker marking 90 cm away from the cap. This activity (see figure 11) helps you to figure out three types of obstacles: uneven pavement with the height of the cap, the circumference needed for a wheel chair to rotate, marked the radius with the help of the chalk, and the minimum space (90cm) needed for a wheelchair to go on the sidewalk without any obstacle. Whenever an obstacle was founded, a mark was made as warning with the paint.

Figure 11. Obstacles finding kit guide. (Mansilla, 2016b)

After the walk we went back to the lecture room where we started, where everyone shared their pictures and we talk about the things we found, like small and severe obstacles, possibilities of improvement and areas of opportunity.

And finally, after we enlisted the topics that the participants noted, I asked them to create a proposal of their own, following the methodology used at the CIVITAS Training on Access Management that took place in Brussels, presented by Teije Gorris (2015) from DTV Consultants. This was made using a set of maps, markers and elements to write and draw, then projecting on a screen each one of the proposals, where every participant explained their thinking about the issues founded and how they think it can be solved.

III.3. ANALYSIS OF DATA

After gathering all the relevant information, from bibliography, climate records, interviews, files and other data provided by the interviewees and the material gotten from the mobility workshop, everything is evaluated and combined to produce, in first instance, a set of drawings, diagrams or sketches that help to understand and display in an easy manner the ways how the mobility problematics can be addressed, especially in cities with warm climate, using the specific data of the case study area to exemplify the information.

These analyses are made in a qualitative approach, also including statistics from INEGI, results of surveys made by IMPLAN Hermosillo, information given by the Patronage and IMPLAN, data from the mobility workshop and annotations, photographic evidence and other info compiled by myself from several visits to the site, resulting in a series of design principles to be described in Chapter VI.

III.4. DESIGN PROPOSAL

The components of the streets are analyzed to review the needs of the specific location, creating drafts of design elements to include in the proposal. The selection of the mobility strategies, like pedestrianizing streets, widening of sidewalks, reduction of width of car lanes, rerouting of public transport, relocation of bus stops and direction of way of streets, results from the identification of the best conditions to improve public life on downtown’s streets. This is made following Jeff Speck’s method (Speck, 2012):

> “When I do a walkability plan, it is a multistep process. First, I study every street that has a chance of being walkable and I grade it in terms of its urban qualities. I ignore the street’s traffic characteristics, since they are simple to fix, and look only at comfort and interest: spatial definition and the presence of friendly faces. This effort produces a map in which the streets are colored from green through yellow to red based on their potential to attract pedestrian life. From this map, a pattern emerges, in which certain

> streets that are good enough come together to form a clear network of walkability. I then supplement this network with the additional streets that are necessary to connect it to the key anchors that it almost reaches, including other pieces of itself.
>
> The result is an urban triage plan: streets are either in or out. This plan mandates the pattern for both public and private investment over the next decade. Only the "in" streets are to receive walkability improvements like safer traffic patterns, street trees, and better sidewalks. Only the "in" street properties are to receive city redevelopment support, whether that means money or just expedited permitting […] Ideally, the entire of the city leadership, both public sector and private sector, comes together around a simple understanding: Building These Sites First".

The final proposal is shown with sketches, figures, tables and maps, as well as a description of the actions taken.

CHAPTER IV. **CASE STUDY**

IV.1. DELIMITATION OF THE STUDY AREA

Hermosillo is located on the north-west region of Mexico, in the State of Sonora, around the latitude 29.08ºN and longitude 110.9ºW, with an altitude of 210 m., within the arid zone of the Sonoran Desert, condition that defines the climatic characteristics of the city.

Figure 12. Map of Mexico. Source: Elaboration: Hugo Moreno Freydig. Data obtained from INEGI, 2015

The city of Hermosillo was originated in the foothills of the *Cerro de la Campana* ("Hill Bell") around the year 1700 as a Presidium and later an Estate (Hacienda) and a Ville with the name of Pitic (see figure 12), changes its name in 1828 to Hermosillo, being designated in 1879 as the capital city of the State of Sonora. (Duarte Aquilar, 2003)

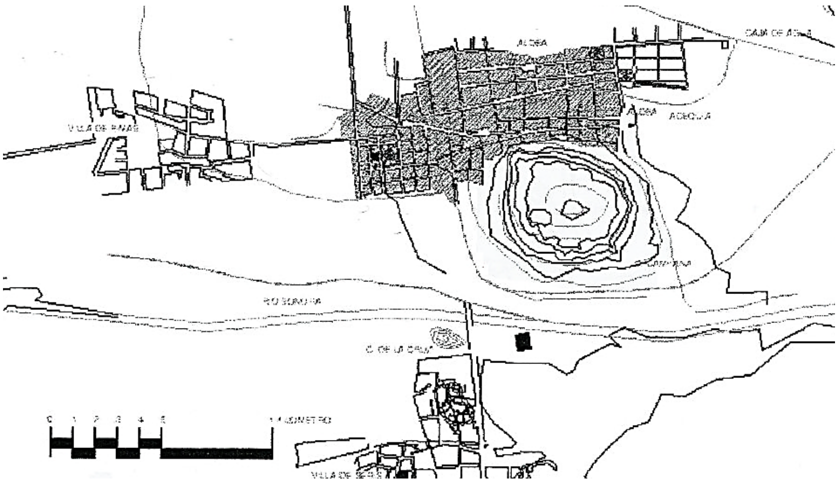


Figure 13. Villa del Pitic in 1800. (Loredo, 2002)

With a population of 884 273 inhabitants (INEGI, 2015b) and density of 58 inhabitants per square kilometer (COESPO Sonora & CONAPO, 2014), the city of Hermosillo has the highest Human Development Index in the state, with a HDI of 0.810 considered as very high, with conditions similar to those founded in Chile, above the global mean of 0.69 and the Mexican mean of 0.71 (UNDP, 2014). This means that Hermosillo has a high potential for development and comparable quality of life.

The Municipality of Hermosillo is responsible for the 53.6% of the GDP of the State of Sonora, having as main economic activity the services, with a 42.5% and commerce with a 37.3%. (INEGI, 2014)

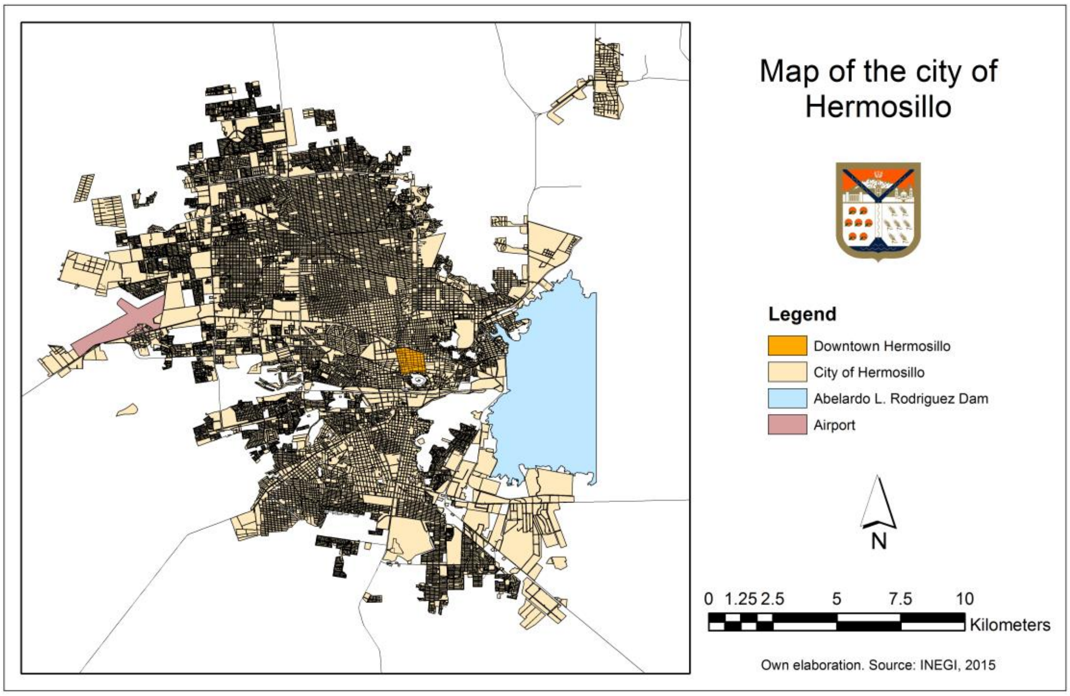


Figure 14. Map of Hermosillo. Elaboration: Hugo Moreno Freydig. Data obtained from INEGI, 2015

The downtown area consists of around 776,500 m^2, and is delimitated on the north by the Blvd. Luis Encinas, south by the avenues Obregón and No Reelección, east by the street Revolución and west by the street Av. Rosales (see figure 15; see more detailed map in annex A).

This is the designated area where the Patronage has influence, being this zone the most traditional shopping zone of the city, where hundreds of stores, historic buildings and different activities take place. Therefore, this is the main area to focus on by this thesis project, nevertheless, because of its importance to the city and the areas around it, like the main plaza of the city, the cathedral and the government buildings, as well as the University of Sonora, the Madero Park and the touristic viewpoint of the De la Campana Hill, the surroundings and the connection to the rest of the town is also taken into account.

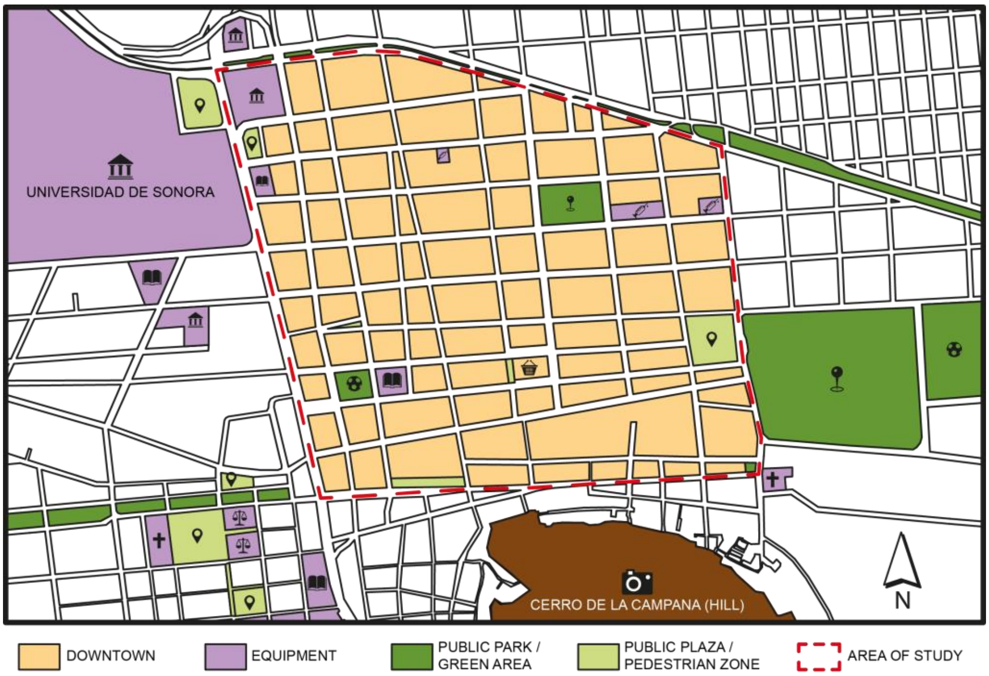


Figure 15. Map of the current state of the area of study and its surroundings. Elaboration: Hugo Moreno Freydig. Data obtained from INEGI, IMPLAN Hermosillo, Patronato Pro-Obras del Centro Cívico y Comercial de Hermosillo, OpenStreetMaps, Google Maps.

Regarding the land use of the area of study, IMPLAN Hermosillo has published an official map, describing each one of the different possibilities of activities.

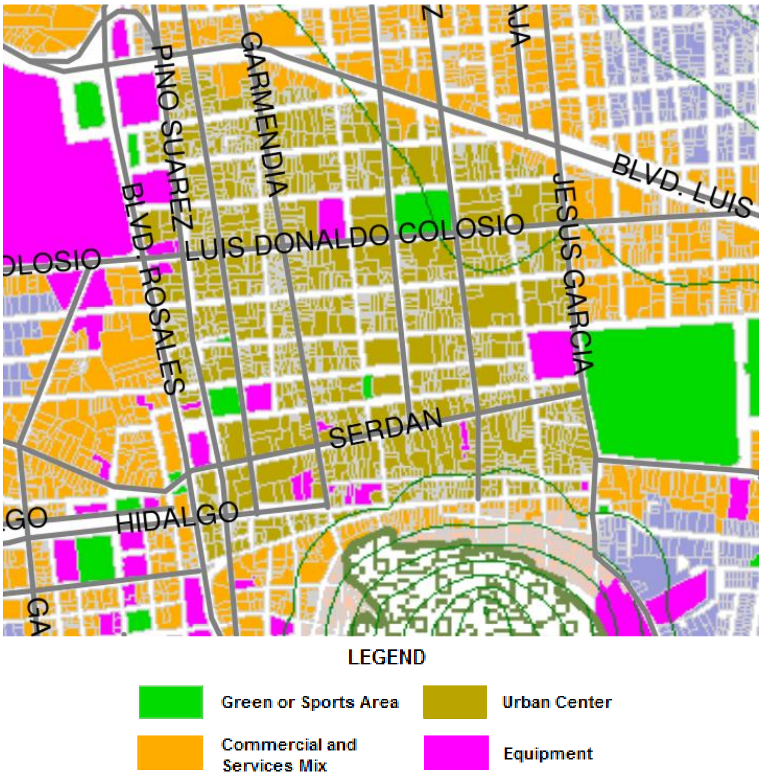


Figure 16. Section of Land Use Map (IMPLAN Hermosillo, 2014)

The following categories are the official land uses existing in the zone according to IMPLAN Hermosillo (2012) [10]:

- **URBAN CENTER:** The zone of the center of population consists in the central and historic core of the city, also defined as the first frame of the city, where the mix of commercial and services uses are the main characteristic, concentrating commercial activities covering the center of population. The existing housing uses must be preserved, promoting an adequate mix of compatible land use that keep the typical characteristics of the urban center, which shall be subject of development and preservation policies. It won't allow the inclusion of industrial land use other than the local/neighborhood industry, and it won't be recommended the incorporation of big impact commerce and services. Heavy traffic is not permitted in this zone and unnecessary traffic through the zone must be avoided.
- **COMMERCIAL AND SERVICES MIX:** These are the zones that concentrate commerce, services and equipment in a sector or group of sectors coverage. Usually located in nodes formed by the crossing of two structural roads or in front of urban corridors. They're characterized for being high density zones, where shops, services, multifamily housing and health equipment, emergencies, administrative and others are grouped.
- **EQUIPMENT ZONES:** Includes lots or areas to be allocated for a public purpose or public interest; they are public property at all levels of government and agencies, enterprises or parastatals, as well as those organizations and associations for assistance, social work, religious associations and others that provide a service of public interest. These also include zones that, due to its location and characteristics, are suitable for inclusion of future equipment.
- **GREEN OR SPORTS AREA:** (No official description) Includes public parks, plazas, and areas for recreation or sports.

As seen in figure 16 most of the area of study is colored as Urban Center land use, therefore the area is not precisely described to the real use of every block and every street. The findings obtained by the exploratory visit will be presented in Chapter 5.

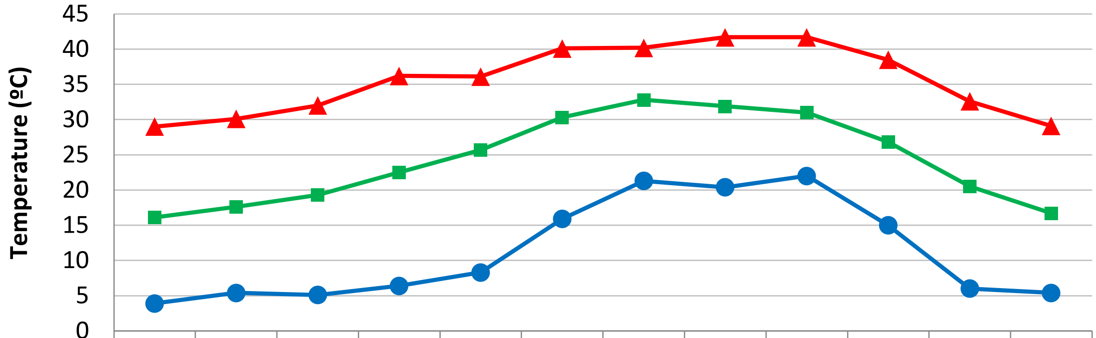
IV.2. CHARACTERIZATION OF CLIMATE CONDITIONS

According to the SIGE system of INEGI, the type of weather that mainly covers the area of assessment is Very Dry Hot with Rains in summer. According to Enriqueta García (1964) defined as BW(h')hw(x')(e') [deserted climate, with annual average temperature over 22ºC, rain season in summer with some rain in winter, and very extreme climates of the northwest, with temperature oscillations over 14ºC] (García, 1964). The city presents a total annual precipitation of 242.7 mm. Having most of the

[10] Translation from original Spanish made by Hugo Moreno Freydig

amount of rain in July and August, with an average of 74.2 mm. Average temperatures around 22 ºC. (INEGI & García, 1999)

Hermosillo presents very high temperatures in summer, typically reaching over 45ºC in the hottest days, this is due to the location of the city, which is within the region of the Sonoran Desert, conditioning these climate properties. The highest temperatures come usually in June, July and August, where June presents a dry weather, and in July and August is the rainy season.



	ENE	FEB	MAR	ABR	MAY	JUN	JUL	AGO	SEP	OCT	NOV	DIC
MAX	29	30.1	32	36.2	36.1	40.1	40.2	41.7	41.7	38.5	32.6	29.1
MED	16.1	17.6	19.3	22.5	25.7	30.3	32.8	31.9	31	26.8	20.5	16.7
MIN	3.9	5.4	5.1	6.4	8.3	15.9	21.3	20.4	22	15	6	5.4

Graph 3. Mean temperatures registered in Hermosillo. (Data retrieved from Meteonorm database)

As shown in Graph 3, the months of June to September of the year temperatures are located, taking maximum monthly average greater than 40ºC.

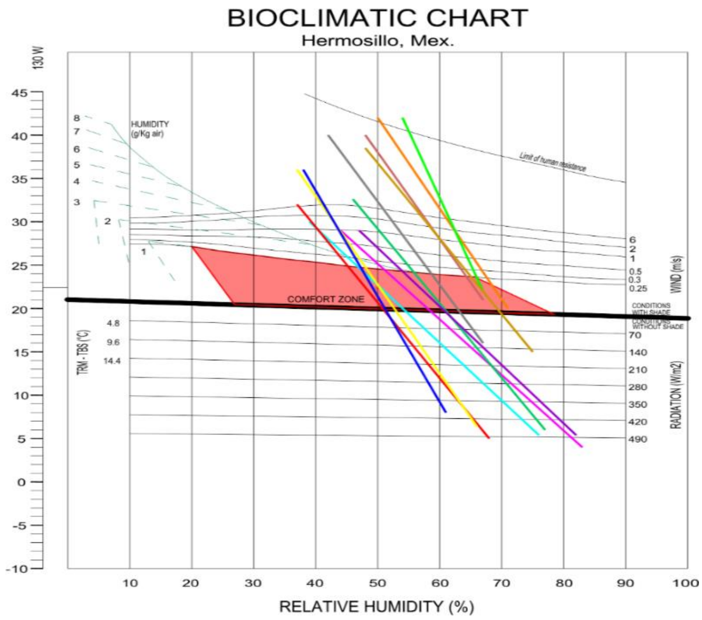


Figure 17. Olgay's bioclimatic chart for Hermosillo, Sonora. Meteonorm database

Figure 17 shows the monthly average weather conditions existing in Hermosillo. Each of the colored lines representing a month, which consists of a colon that are obtained by combining the monthly average maximum temperature with the monthly average minimum monthly average humidity and monthly average minimum temperature with the maximum humidity. This lets you view the parameters of the present climate in the city and at what times is within a comfort zone (temperatures roughly between 20 and 25º Celsius, depending on the combination with other conditions like humidity and wind), highlighted in red. As noted, rarely during climatic variables have favorable conditions for comfort, with the greatest impact when the temperature exceeds nice values, which occurs in much of the year, especially from May to October.

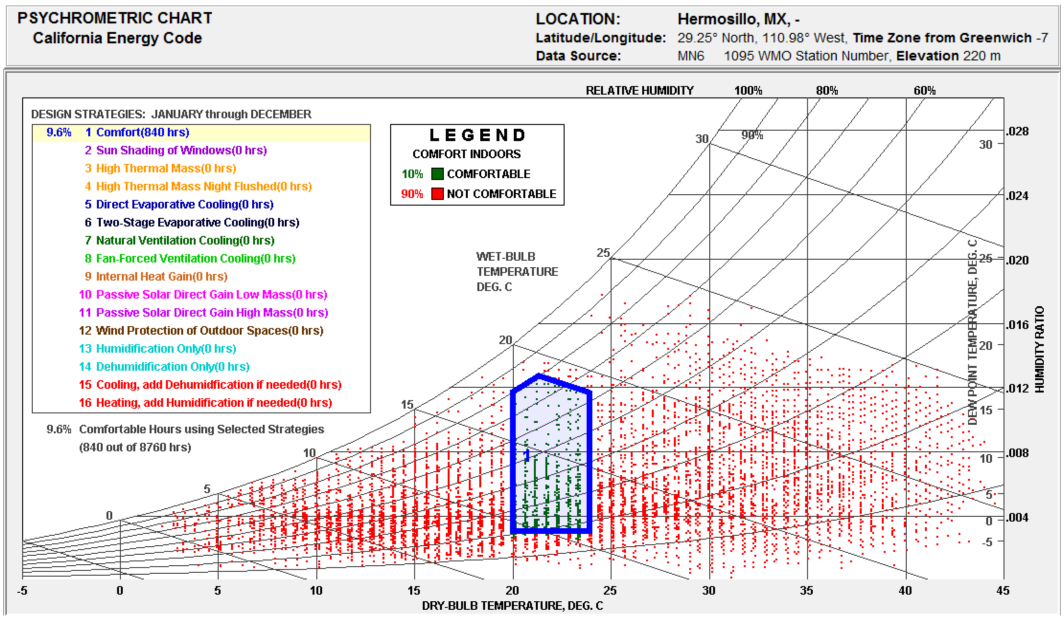


Figure 18. Psychrometric Chart for Hermosillo. Source: Climate Consultant software, with information from Meteonorm Database

Figure 18 shows the daily average weather conditions for Hermosillo, where every dot in the chart is the measure of a day in a complete year. The blue polygon represents the comfort zone, where every green dot consists in one measure where the combination of temperature and humidity provided comfortable conditions. As shown by the Psychrometric Chart, only 9.6% of the year is the weather in Hermosillo within comfortable values.

Regarding to the sun's apparent trajectory (see figure 19), due to the location of the analyzed zone, the position of the sun is never in the zenith, where the most serious point in the summer solstice, casting shadows slightly from the north early in the morning and late in the afternoon. It is also a critical position from spring equinox through summer to autumn equinox after 17:00 hours, due to the near-horizontal position of the sun, which makes it harder to create sunscreens.

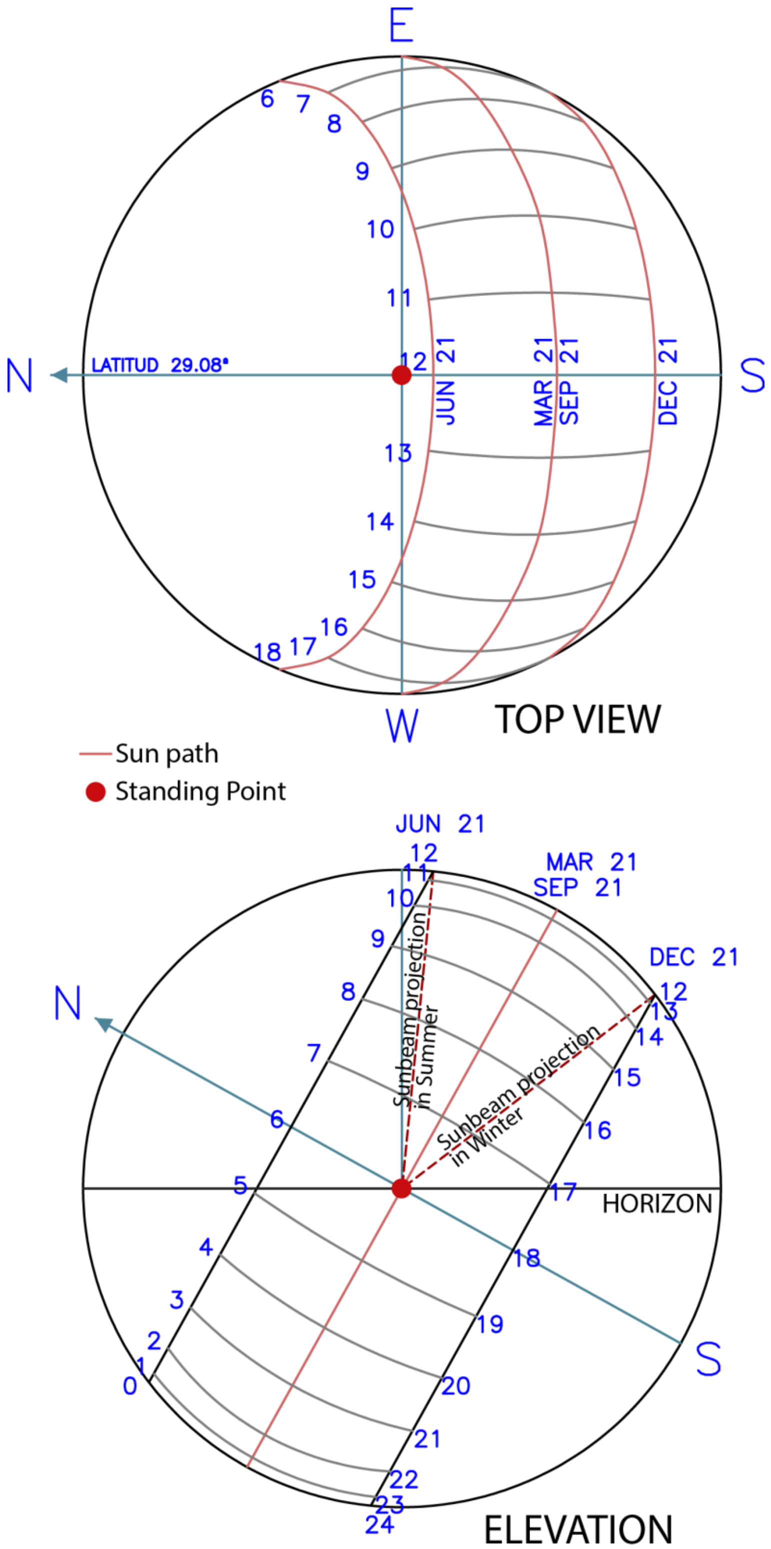
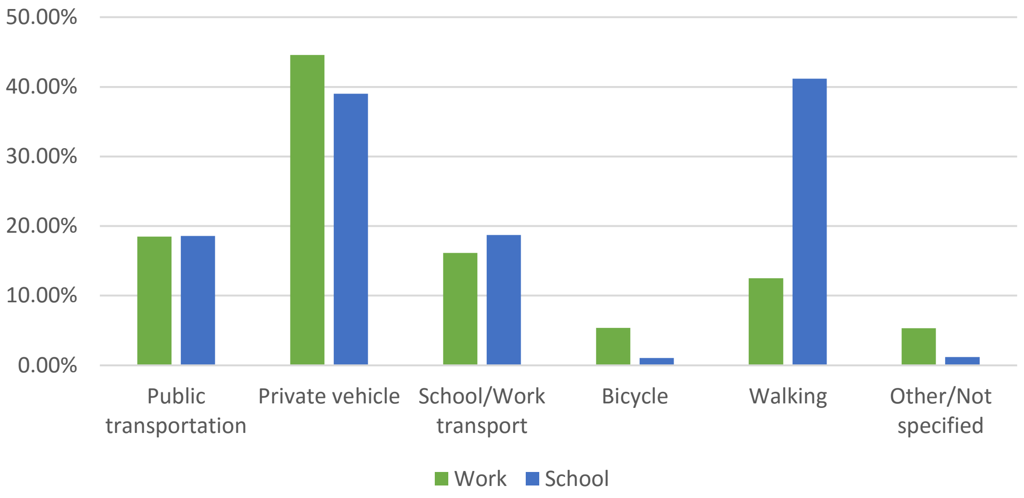


Figure 19. Basic sun path analysis for Hermosillo, Mexico

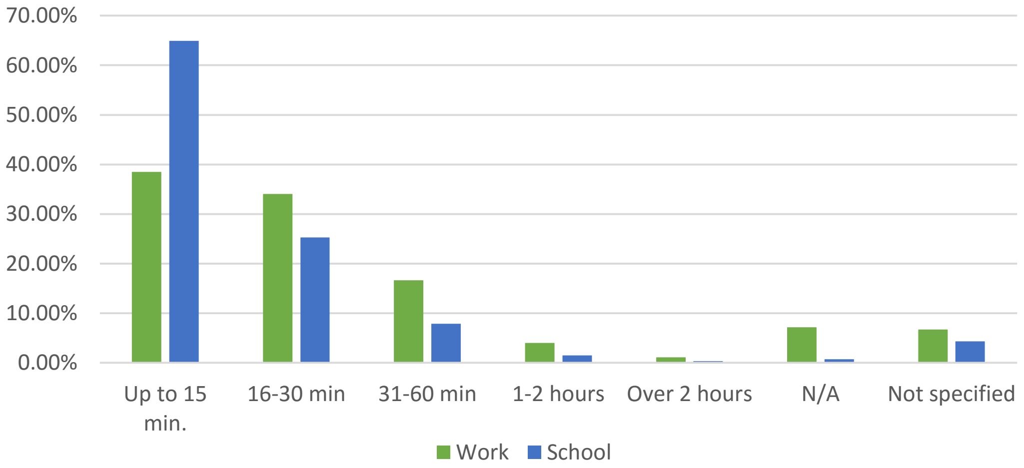
IV.3. MOBILITY SITUATION

As most of the major cities in Mexico, Hermosillo has nowadays an important challenge regarding mobility and accessibility inside the urban sprawl. The city has low population density (58 inhabitants/km2 (COESPO Sonora & CONAPO, 2014)), this means that a high amount of land is used in relation to the quantity of the population, therefore a large investment is needed to provide all the people with basic infrastructure, due to the extensiveness of the urban sprawl.

According to INEGI (2015a) in the State of Sonora, the ways people commute to workplace is mainly by automobile, as well as walking for students.



Graph 4. Mode of transportation used by people in Sonora[11]. Source INEGI (2015a)



Graph 5. Time needed to commute for people in Sonora[14]. Source: (2015a)

[11] *The sum of the different categories in graphs 4 and 5 can result more than 100, because some of the interviewees use several methods of transportation for an everyday trip*

Regarding the modal split of people that go to the downtown's shopping area, the President of the Patronage said in an interview that between 75 and 80% of the costumers arrive by bus (Romero & Robles, 2016)

According to a poll made by IMPLAN Hermosillo (2016) the costumers of the downtown's shopping area of Hermosillo come mostly from the neighborhoods: Sahuaro, nuevo Hermosillo, Olivares, Palo Verde, Ley 57, San Benito, Solidaridad, Centro, 5 de Mayo and Pueblitos (among others) (see figure 20).

Figure 20. Places of Hermosillo where the costumers of downtown area come from[12]. (Own elaboration, with information from IMPLAN Hermosillo)

CTS EMBARQ Mexico (2009) declares that to increase non-motorized mobility, the amount of local trips made by feet or by bike must be encouraged by offering a

[12] Size of circles corresponds to the approximate area of the neighborhoods, not to the amount of people from that area.

comfortable, safe and attractive experience, with distances of about 15 minutes of travel time, equivalent to around 1 km walking 4 km by bicycle.

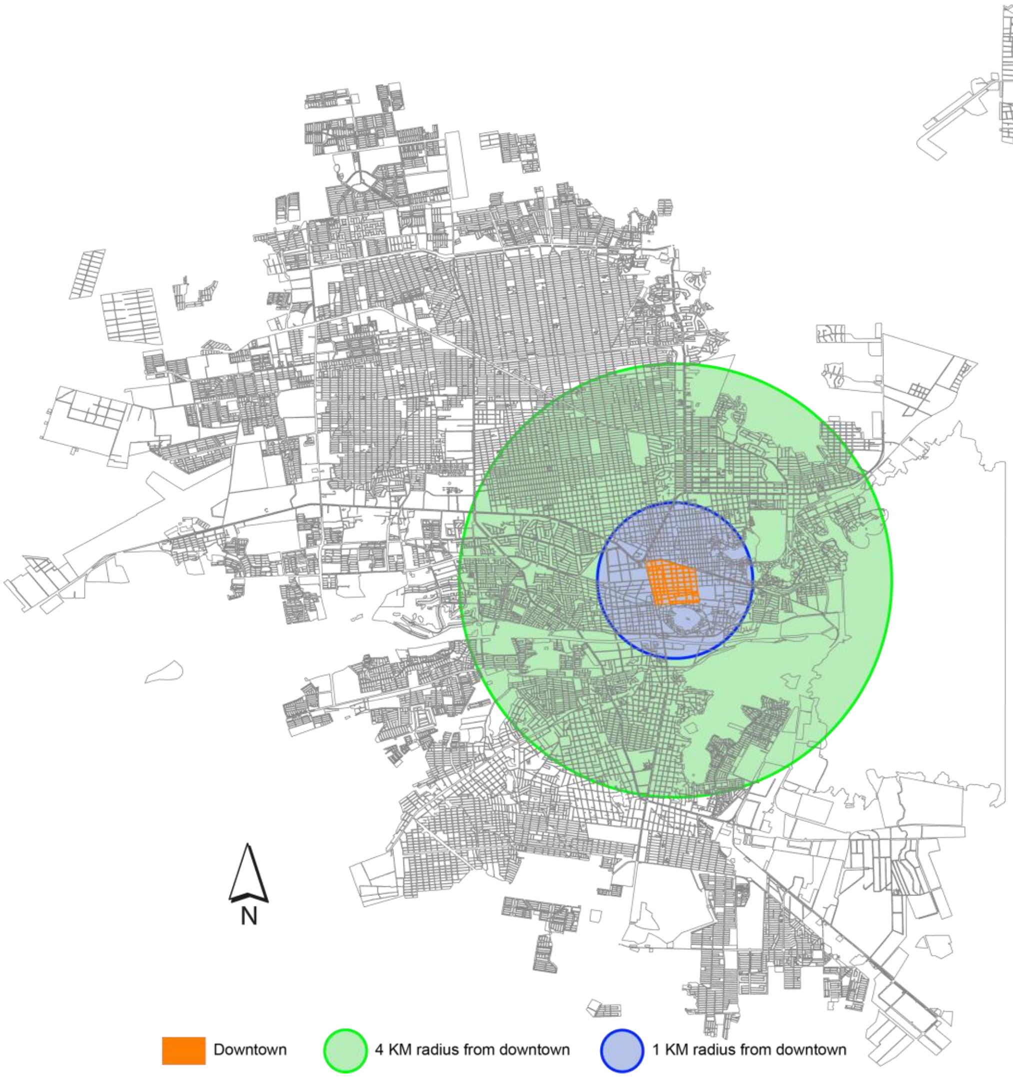


Figure 21. Radius of 1 km. for pedestrians and 4 km. for bicyclists to reach downtown Hermosillo.

This means that a good portion of the city, around downtown area, is able to access to it by walking and by bike. Of course this distance, considering the climate conditions, might be decreased in summer, due to high temperatures, especially in the afternoon, nevertheless it would be possible to travel long distances early in the morning or after sunset, when temperature is more pleasant.

Regarding the infrastructure conditions in Hermosillo that specially affect pedestrians, INEGI (2015c) presents a set of maps that show the availability of sidewalks, ramps and trees in the streets as shown below.

Color green represents availability in every road, yellow means available in some roads and red denotes no availability in any road of the zone.

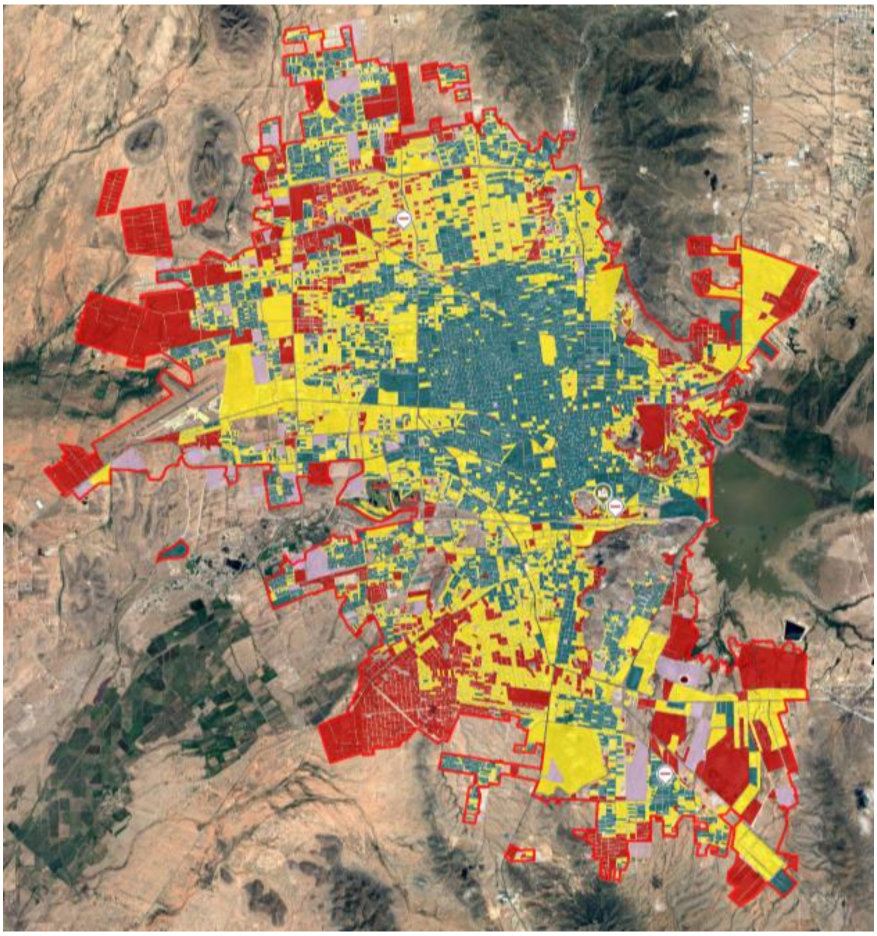


Figure 22. Availability of sidewalks in Hermosillo (INEGI, 2015c)

Figure 23. Availability of sidewalks in the area of study (INEGI, 2015c)

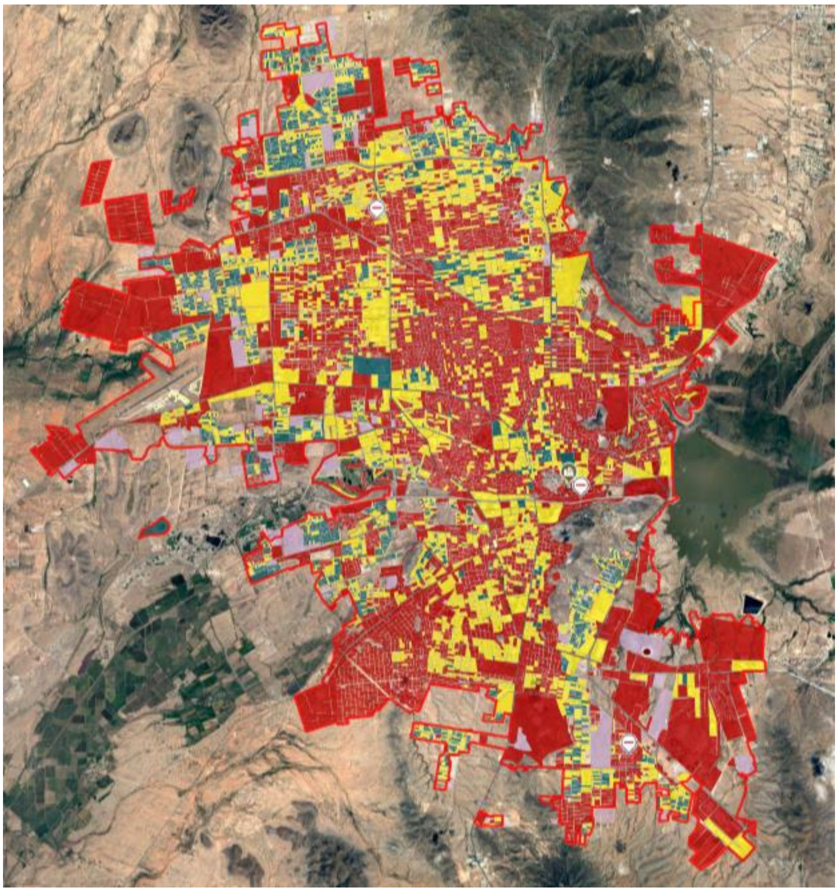


Figure 24. Availability of ramps and accessibility for people with disabilities in Hermosillo (INEGI, 2015c)

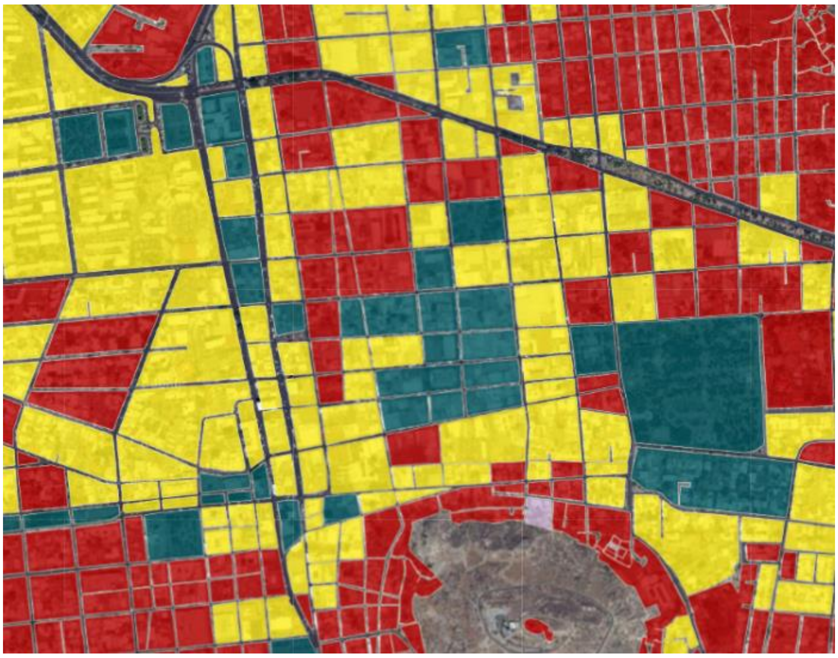


Figure 25. Availability of ramps and accessibility for people with disabilities in the area of study (INEGI, 2015c)

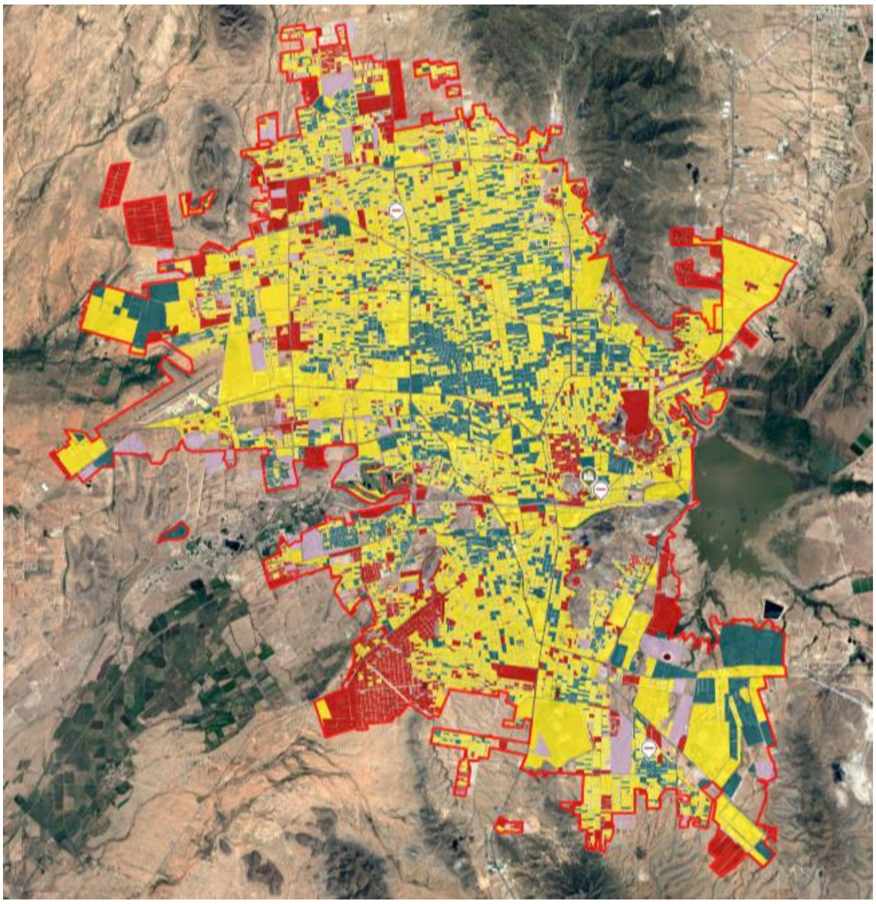


Figure 26. Availability of trees in roads in Hermosillo (INEGI, 2015c)

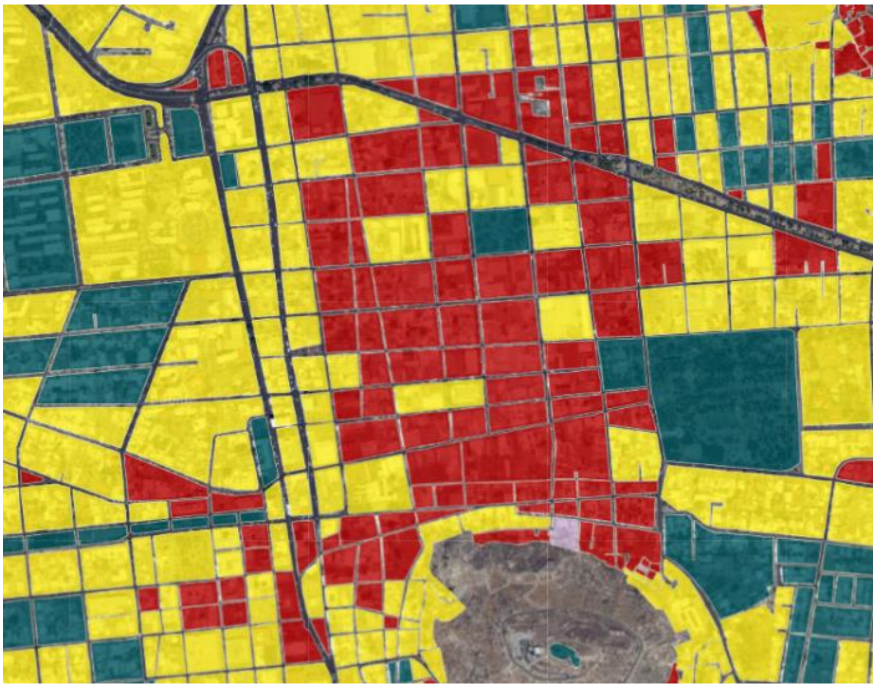


Figure 27. Availability of trees in roads in the area of study

Figures 22 and 23 show the availability of sidewalks, where in the city as a whole, there is a lack of sidewalks in 18.71% of the road, whereas in downtown there is no lack of sidewalks.

Regarding the availability of ramps, figures 24 and 25 show that in the city there are ramps for people with disabilities in only 18.25% of the roads, and the city center has 21.35% of availability.

Speaking about trees in roads, the city in general has a high insufficiency, where only 24.70% of streets have trees, nevertheless, the area of study is even worse, having a tiny 3.37% of roads with vegetation (see figures 26 and 27). (INEGI, 2015c)

Over the past few years, there has been a growing movement in Hermosillo for the use of bikes in the city. Despite the current lack of good infrastructure capabilities and the weather conditions. Due to this growing demand for cycling facilities, the City Government has begun to concern about this topic, therefore a project for introducing cycle paths on the streets is currently in development. According to the *Programa de Desarrollo Urbano de Centro de Población de Hermosillo* (Urban Development Program of Hermosillo), several cycle paths are considered to be implemented in different stages, nevertheless the map that shows them needs to be revised, due to some misinformation founded on it (see map in Annex B). It contemplates 125 km of cycle paths and declares that some of them would be protected bike lanes, others buffered (separated with paint on the pavement) and others would be simple bike lanes (marking the path with painted lines), though it doesn't specify where would be each case. (IMPLAN Hermosillo, 2015)

Figure 28. Example of cycling infrastructure project by IMPLAN (IMPLAN Hermosillo, 2016b)

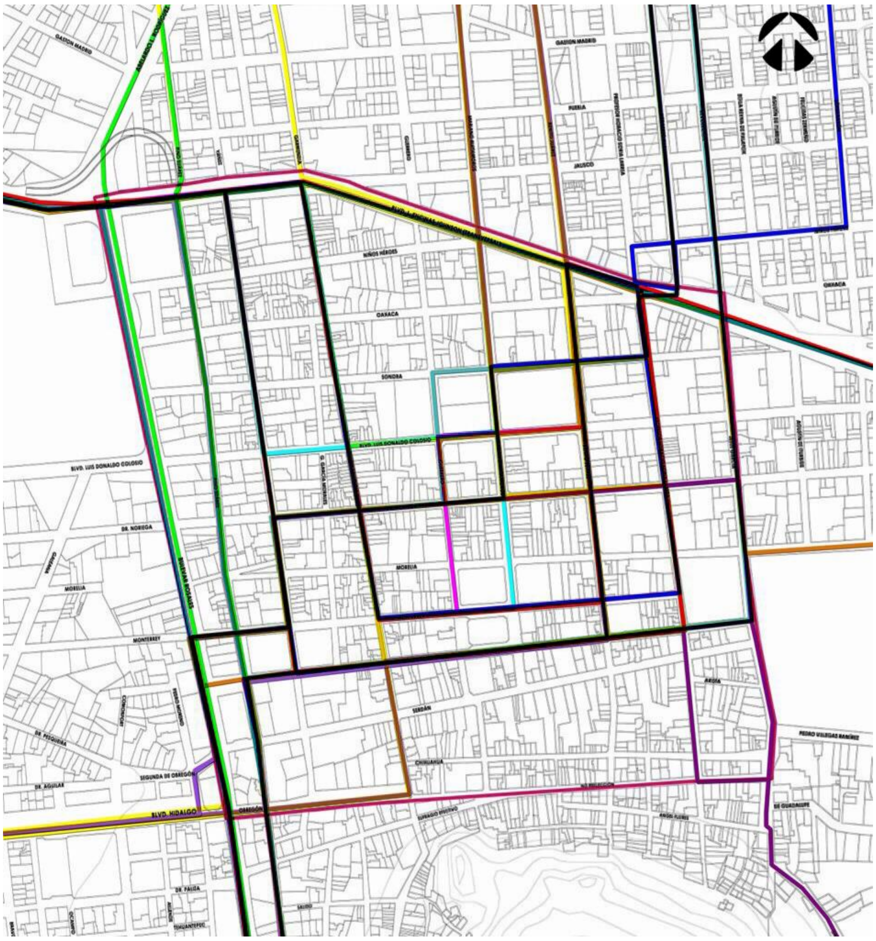


Figure 29. Map of public buses' paths across downtown Hermosillo. Source: IMPLAN Hermosillo, 2016

Regarding the service provided as public transport, there is only one system for the whole city, it consists in a series of bus routes that try to provide accessibility all over the urban sprawl, however it has several problematics like inefficiency of the network to accommodate as much area of the city as possible, having several old buses and low quality of the service provided.

In the past, two of the governors of Sonora have attempted to improve the conditions of the public transport system, first called “SUBA”, promoted by the Governor Eduardo Bours in 2007, and the second denominated “BUS Sonora” by the Governor Guillermo Padrés in 2012. With *SUBA* the project tried to change the routes, renew the bus fleet and provide better service, though the change of routes was not well received by the population, so the governor took a step back and used the new buses with the old routes. Years later, *BUS Sonora* looked to revamp the bus units and improve some administrative issues with the companies that provide the service, and even launched a tracking system that gives the users the possibility to see the routes and the current position of the buses via a smartphone app. Despite these improvements, the service keeps having problems (Ayala, 2013; Lozano, 2016; Palomino, 2016) like routes not well designed for the current needs of the city, buses are not well distributed along the paths and the city and most of the bus stops are in terrible conditions, or simply there are no official bus stops in many cases.

Specifically talking about the case study area, nowadays the routes go through almost every street of the city center (see figure 29), which creates a condition of having many small bus stops that don't even have a proper area, urban furniture and cover for shade or rain.

Besides the problematics of the city center, along the whole urban area there are some high demand zones, where several bus lines share a single bus stop, creating competence between buses to use the space, which causes that some passenger miss their bus. Furthermore, the city has grown extensively, nonetheless the routes keep their original path, being currently outdated and provoking some people to have to use more than one bus for a single trip, multiplying the cost.

Another severe mobility problem founded near downtown area, located right in the most important boulevard of the city, Blvd. Luis Encinas, in a pedestrian crossing that links the campus of the University of Sonora with the General Hospital of the State of Sonora. Thousands of pedestrians cross this boulevard, because it is a very important hub for several bus routes in both sides of the street. A similar thing happens at the intersection between Blvd. Luis Encinas and Blvd. Rodrigues/Rosales, where a big number of cars transit daily, and there is lack of safe pedestrian crossings. These have already caused accidents and even deaths by cars running over pedestrians. (Celaya, 2013; Redacción El Imparcial, 2016; Uniradio Noticias, 2016)

In 2014 a pedestrian overpass (see figures 30 to 34) was built in this location, but this type of infrastructure is in reality designed for cars not to stop, they aren't really made for the people (Díaz, 2012).

Figure 30. Overpass built in Blvd. Luis Encinas, Hermosillo

The problem with this is that it removes the traffic light, allowing cars to go faster through the boulevard, which causes difficulties for pedestrians, for combining the students of the University with the patients and visitors of the Hospital, making them walk longer, go up several meters (especially hard for people with disabilities and elderly).

With this overpass, pedestrians have to walk 237.7 meters, this is equivalent to walk over 2 times the size of a football field, just to cross the boulevard, which is only 35.6 m wide. This is the first overpass in Hermosillo that is built with ramps.

Figure 31.Overpass in Blvd. Luis Encinas (Satellite image source: Google Maps)

Figure 32. Overpass in Blvd. Luis Encinas, length equivalent to over two football fields (Satellite image source: Google Maps)

Figure 33. Pedestrian's obstacles due to overpass

Figure 34. Transit merge difficulties due to overpass

Figure 33 illustrates the obstacles that cars result for pedestrians in this intersection. Figure 34 shows the problematic that is the merge of transit in Boulevards Navarrete and Luis Encinas and the exit of cars from the University campus in peak hours, due to the lack of traffic lights to regulate traffic, caused by the implementation of the overpass.

This type of infrastructure goes against the *Carta Mexicana de los Derechos del Peatón* ("Mexican Chart of Pedestrians' Rights"), which in its premise number seven says that pedestrian's crossings that aren't on ground level are unacceptable, and nobody should be judged or discriminated for avoiding or rejecting its use. (Liga Peatonal, 2014). This document is made by an ONG called Liga Peatonal and is a non-mandatory publication that encourages government, stakeholders and people to work for having a more inclusive, accessible and friendly city.

CHAPTER V. **FINDINGS**

In figure 16 it was shown the official land uses of the area of study, as well as its surroundings, which is mostly one single type for most of downtown, for this reason I did a bike ride for every street of the zone, doing annotations regarding the actual types of use founded. The current uses are divided in Commercial, Housing, Equipment and Mix (combination of the above). The annotations were marked on the street, instead of inside the blocks, because this study focuses on the public spaces, so what I tried to show is the types of activities that can be founded when walking through the zone (see figure 29). This is helpful to understand what happens in downtown area and provide information to take decisions to propose improvements on the public space of the study area.

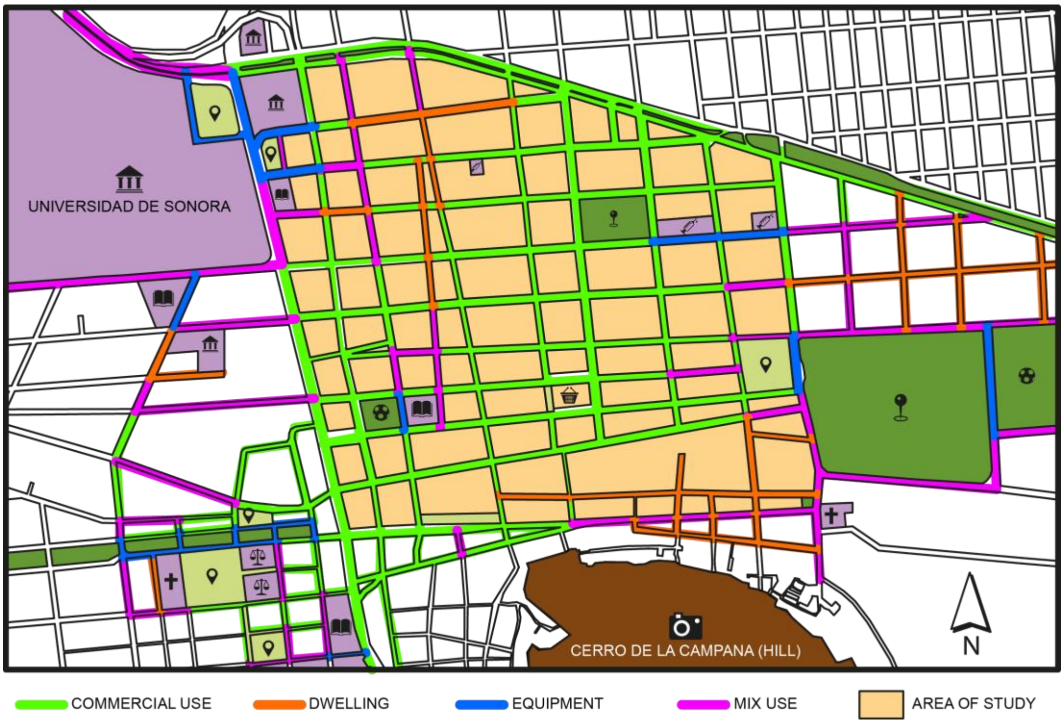


Figure 35. Map of current land use of the area of study and its surroundings

As mentioned before, IMPLAN Hermosillo has already a project that is currently ongoing, where they seek to pedestrianize some of downtown's streets, however some of the concepts that IMPLAN is proposing need to be revised.

An example of this is shown in figure 36, where the current status (top drawing) of the street involves two sidewalks of 1.45 and 1.30 m, but their proposal (bottom drawing) for this street reduces sidewalks to only 0.60 m, which makes it impossible for a wheelchair to go through, creating new accessibility issues, instead of fixing them.

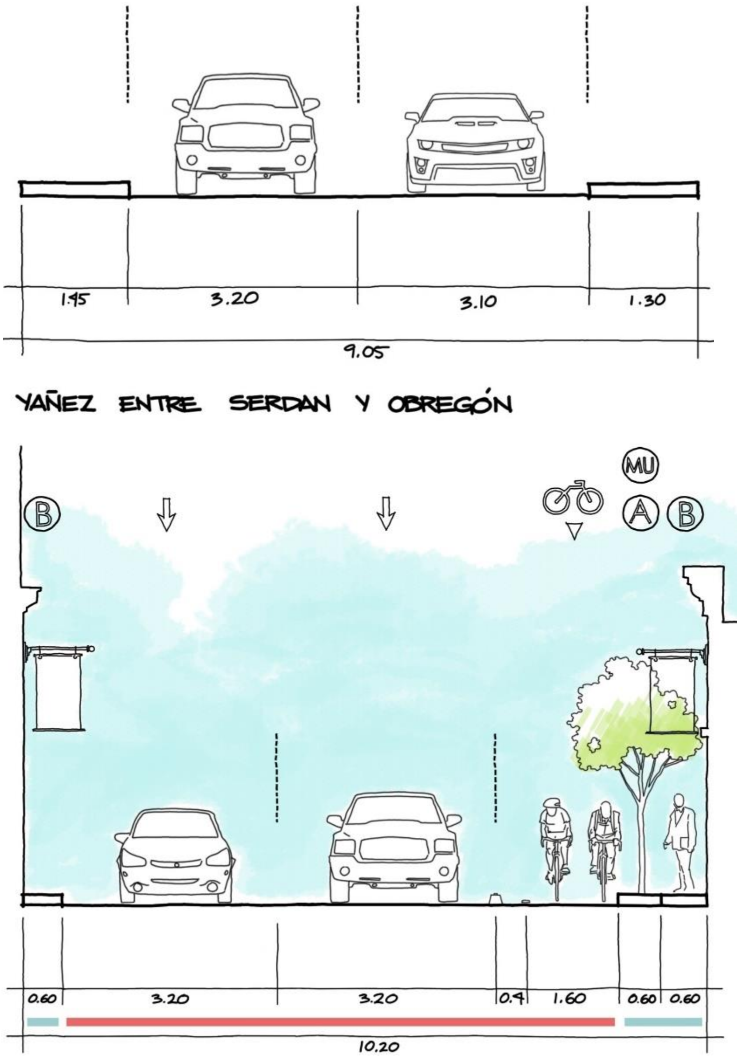


Figure 36. Current state and IMPLAN's proposal for the street 'Yañez' (IMPLAN Hermosillo, 2016a)

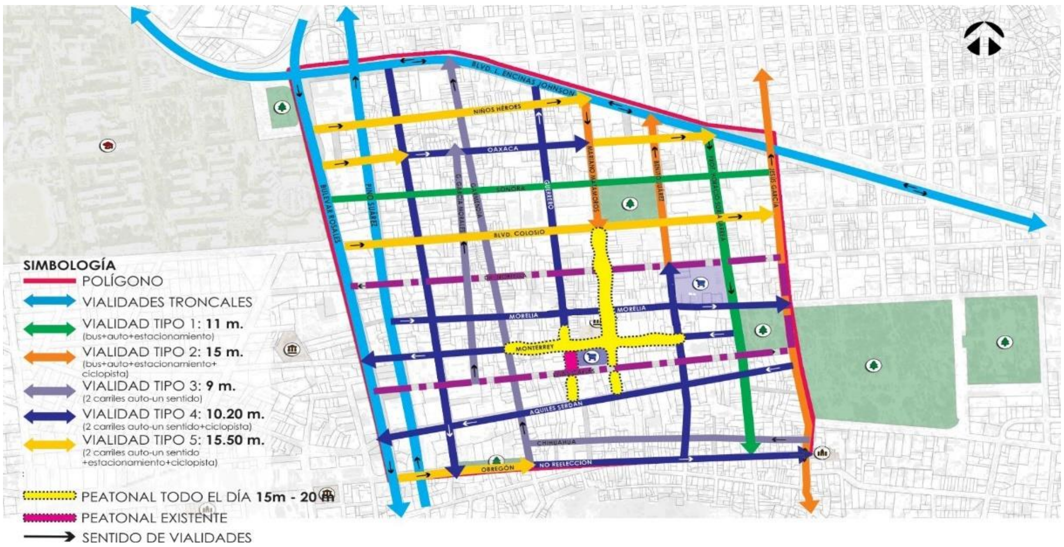


Figure 37. Map of mobility proposal by IMPLAN (IMPLAN Hermosillo, 2016a)

Figure 37 shows a map presented by IMPLAN Hermosillo as proposal for improving mobility in the center of Hermosillo, where the lines colored in yellow represent the areas to pedestrianize, nonetheless figure 38 shows a photomontage view of the street Guerrero, displaying bike lanes and car lanes in a street that according to the map should be pedestrian. Also the bike lanes end in a pedestrian refugee zone, and the sidewalk has no tactile paving for blind people, despite that the corner is full with tactile texture, which could also cause confusion due to the large amount of pavement that is texturized.

Figure 38. Photomontage of intersection between streets Guerrero and Elías Calles by IMPLAN (IMPLAN Hermosillo, 2016a)

Continuing with the same proposal, the intersection between streets Matamoros and Monterrey is correctly pedestrianized in both ways, but has also some tactile pavement details that need to be corrected, the awnings don't project enough shade and the amount of trees is low for the area (see figure 39).

Figure 39. Photomontage of intersection between streets Matamoros and Monterrey by IMPLAN (IMPLAN Hermosillo, 2016a)

Along with the general findings obtained with the fieldwork, the specific necessities of the case study have been categorized according to the three main topics to cover in this work: Pedestrians' needs, Cyclists' needs and Bus passengers' needs. These were obtained by the workshop, observations, photographic documentation and interviews, derived from mobility issues and problematics due to climate conditions. Along with these, some beneficial aspects were also seen.

V.1. CONDITIONS FOR PEDESTRIANS IN THE AREA OF STUDY

Several problematics can found in Hermosillo that affect pedestrians, and in the area of study they even increase in some cases. For example, people have to face narrow sidewalks, obstacles like poles, merchandise, people waiting for the bus without enough space, high steps, trees blocking the way, lack or poorly designed ramps and even cars parked in the sidewalk (see figures 40-46).

Figure 40. "Almost half of the sidewalk is blocked with merchandise" (SIC). Photo: Michelle Martínez, 2016

Figure 41. "How many times have I hit myself with trees like this?" (SIC). Photo: Michelle Martínez, 2016

Figure 42. "Blocking parking and sidewalk" (SIC). Photo: Michelle Martínez

Figure 43. “Privately and publicly interrupted circulation” (SIC). Photo: Oscar Rascón

Figure 44. “Definitely this is a city for vehicles, sidewalk adapts to vehicle access, not vice versa” (SIC). Photo: Oscar Rascón, 2016

Figure 45. "Extremely high sidewalks = ramps with a high percentage of tilt" (SIC). Photo: Oscar Rascón, 2016

Figure 46. "A column is not a good place where to go after going up though a ramp" (SIC). Photo: Oscar Rascón, 2016

Figure 47. Gathering of people in Sunday at “Viactiva”

Figure 48. The only current pedestrianized Street in the study area

On the other hand, some positive things can also be found, for example the variety of activities that are made every Sunday by the “Viactiva” circuit, where some streets that link the Cathedral and central plaza with the shopping downtown area are temporarily pedestrianized, gathering hundreds of people every week (see figure 47).

Another good example of facilities for pedestrians is the segment of the street Guerrero between Monterrey and Plutarco Elías Calles, next to the Municipality Market.

This section of the street is already pedestrianized, and one can almost the entire day find people sitting and gathering in this area, which has also a roof, so it creates a smoother environment to protect from the sun.

When speaking about climate oriented conditions for pedestrians, the biggest issue is the need to be protected from the high insolation that occurs usually from May to October. In order to deal with this, many of the tenants of the shops have installed some tarps, awnings or any other kind of protection, which, in many cases, isn't properly allocated, contributing to the obstacles of pedestrians.

Figure 49. "Awnings to avoid radiation block the free pedestrian circulation" (SIC) Photo: Oscar Rascón, 2016

And, as presented in the map of figure 27, there is almost no vegetation in the whole shopping area, creating a less friendly environment, contributing to rise the temperature (Urban Heat Island Effect) and reducing to a minimum the possibility of people to be protected from sun's radiation.

V.2. CONDITIONS FOR BICYCLISTS IN THE AREA OF STUDY

Regarding the possibilities for bicyclists to ride freely in the city, Hermosillo has a deep problematic, despite the continuous increase of bike riders. One can easily find drain grids that intersect cycle paths, some bike lanes that aren't properly designed or maintained and, of course, lack of bike racks to safely park your bike.

Figure 50. Rainwater drain through current bike path

Figure 51. Bike lane isn't properly paved

Figure 52. "Obstructing because of comfortableness or security?" (SIC). Photo: Oscar Rascón, 2016

Along with these typically found mobility issues for bike riders, in Hermosillo the generalized insufficiency of trees on the streets create a harsh environment for cyclists too, due to the direct exposition to sun, whereas people in their cars at least have a roof that protects them from the sun, and in many cases they have the air condition on.

V.3. CONDITIONS FOR BUS PASSENGERS IN THE AREA OF STUDY

Regarding people that use the bus as mode of transportation, the most common difficulties they have to face are: lack of information of routes and times of service, poorly designed or constructed bus stops, lack of bus stops, narrow spaces for waiting, not enough shade, obstruction with advertisement, high solar radiation that goes all the way through the interior of the bus, thru the windows, and even some buses that have no air condition.

This is a big impact specially for downtown Hermosillo, because most of the routes go through the shopping area, representing the most important mode of transportation for costumers of this place, as discussed before.

Figure 53. "People waiting the bus where there are no signals. Blocking half of the sidewalk" (SIC). Photo: Oscar Rascón, 2016

Figure 54. "People waiting for the bus + People coming out or in the bus = No space to move" (SIC). Photo: Oscar Rascón, 2016

Figure 55. Human behavior facing high sun radiation on public transport in Hermosillo, Mex.

Figure 56. Human behavior facing high sun radiation of bus stops in Hermosillo, Mex.

Figure 57. Human behavior facing high sun radiation of bus stops in Hermosillo, Mex. (2)

Figure 58. Bus stop in Hermosillo that is well designed for the local environment

Figures 55 to 57 show how people manage to resist the sun's radiation and high temperatures in Hermosillo, Mexico, in these pictures people always prefer to look for the shade, even when it requires to behave in uncomfortable situations, like crowding one side on the bus, against a wall under little awnings or standing away from the bus stop, where the sunshade is projected, avoiding the hot surfaces of the benches because they are metallic and receive directly the solar beams.

These images give evidence of bad design practices, where there is lack of infrastructure for people to stay and handle in an easier way the climate conditions. In contrast, Figure 58 shows a good design of a bus stop, also example from Hermosillo, the place of case study; where, as displayed in the picture, the benches are protected from the sun's radiation by the awning and a wall, as well as two trees (*Cercidium microphyllum*) that are endemic from the region, creating a more pleasant microclimate; also includes a garbage bin and enough space on the sidewalk for people to walk through without any obstacle.

That was an example that it is possible to create conditions to manage with extreme climate conditions, it is only needed to perform a study of the sun's and weather conduct to produce well designed infrastructure for every location.

CHAPTER VI. ANALYSIS OF DESIGN PRINCIPLES

As part of the research made in the fieldwork, the two principal categories gotten from the workshop and the results of interviews made by IMPLAN are mobility, safety and heat.

The main concerns are:

- Traffic sings
- Obstruction of sidewalks
- Uneven pavements
- Unsafety for riding bikes
- Lack of trees
- Not enough space to walk
- Lack of accessibility for people with disabilities
- Lack of space for public transportation
- Lack of public transit signals
- Insecurity at night
- Lack of shading areas
- Poorly designed ramps
- Dirt
- Peddlers
- Not enough garbage bins
- Lack of sufficient night lighting
- Parking spaces
- Buses last long to arrive
- Lack of spaces to supply merchandise
- Need to diversify merchandise

From these topics, the resolutions agreed by the interviewees and the volunteers of the workshop to be promoted were:

- Educational cleaning campaigns
- Creating pedestrian streets
- Increase advertising to attract costumers
- Increase open hours on Sundays
- Creating cultural-artistic events
- A paramedic station
- Add awnings, foggers and ventilators
- Redistribute bus paths a little further away
- Create better conditions for walking
- Advertising low prices
- Creating public restrooms
- Putting benches on the sidewalks
- Offering public Wi-Fi
- Building landmarks
- Doing some activities regularly, using the Madero Park
- Promote restoration of façades and the look of downtown
- Redistribute public transport paths to certain streets

Speaking about mobility around the area of study, one of the current projects that the government has is the creation of a BRT system to improve mobility in Hermosillo. From this point, I've created a proposal for a BRT station, performing a sun path analysis to design the envelope of the module, looking to maintain more comfortable conditions inside, regarding temperature and insolation (see pictures 59-61).

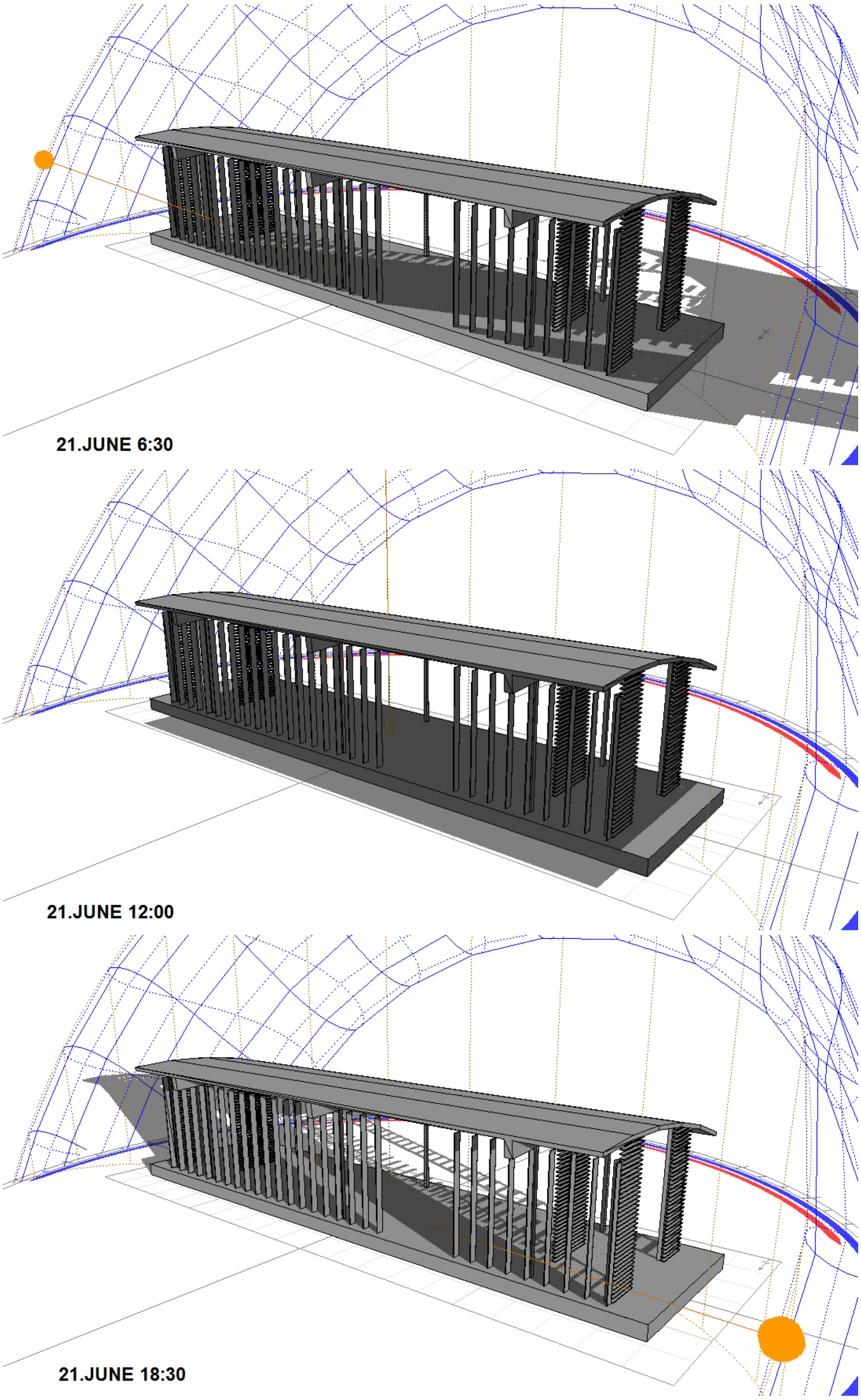


Figure 59. BRT Station proposal, shade analysis summer solstice

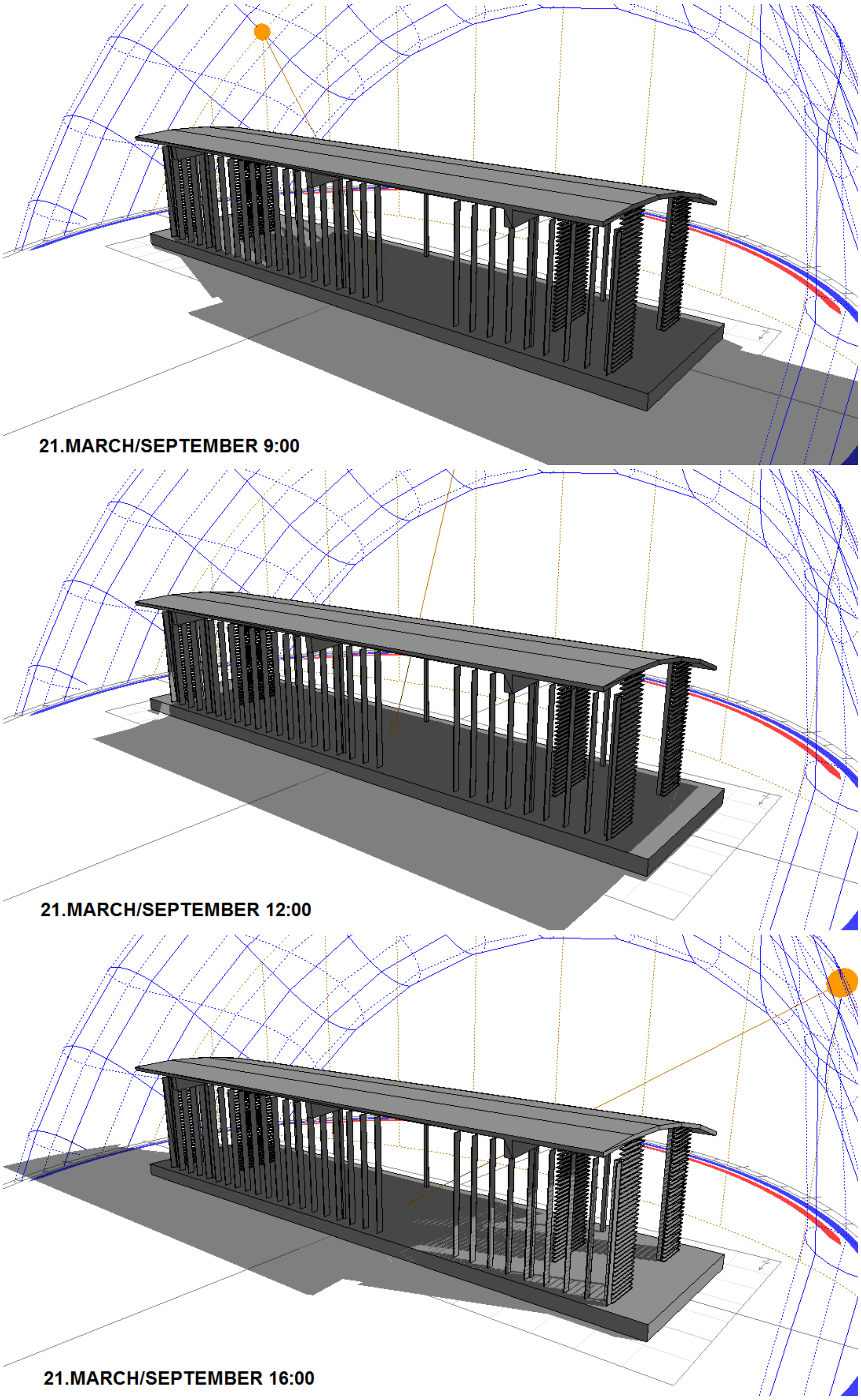


Figure 60. BRT Station proposal, shade analysis spring/autumn equinox

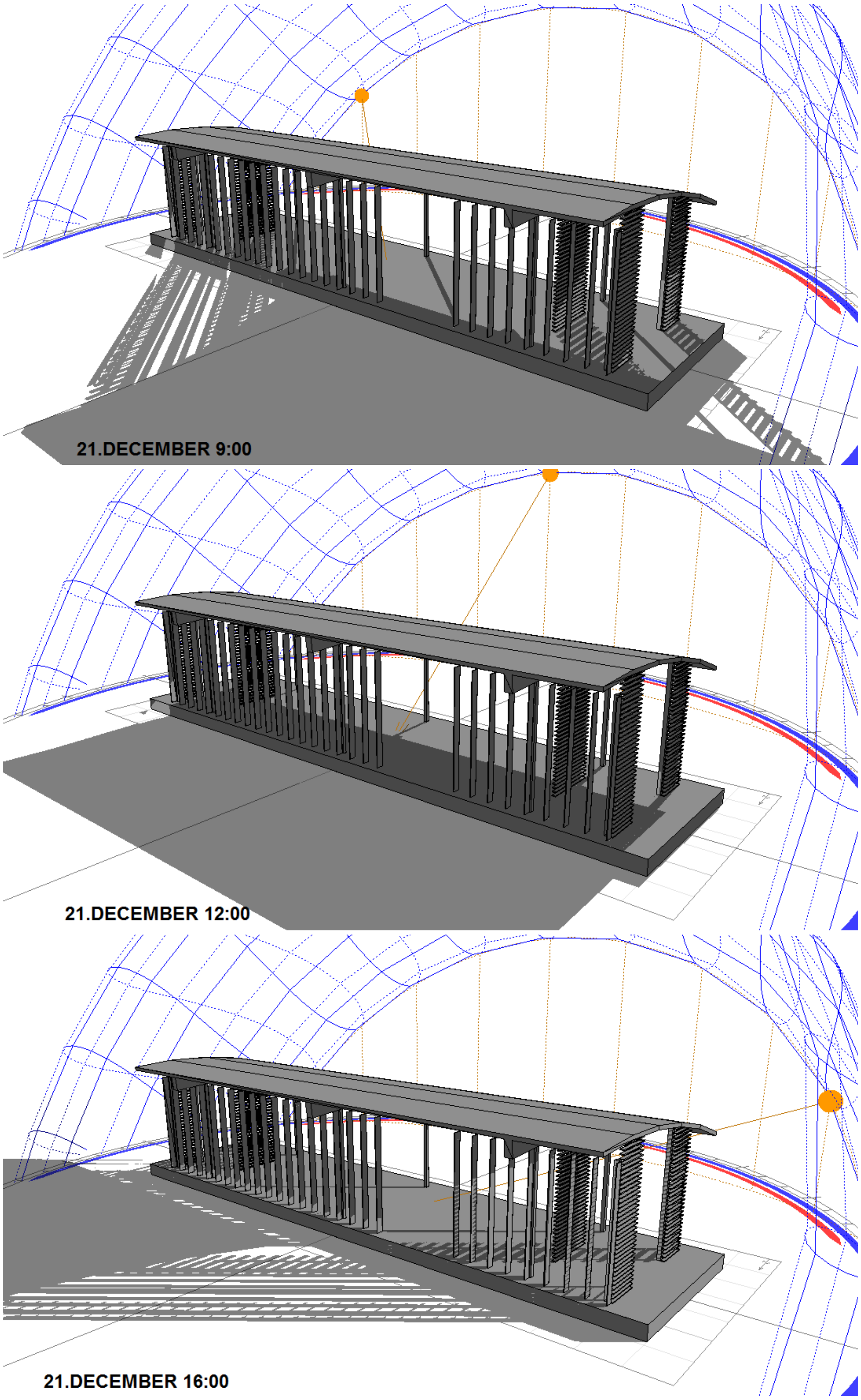


Figure 61. BRT Station proposal, shade analysis winter solstice

These design elements allow the place to be shaded from spring to autumn, maintaining shade in the hottest season, letting the sun beams in on winter.

Along with the BRT station, I have created a bus stop prototype, which also blocks solar radiation in summer, allowing it in winter. These are a set of two models, one for the orientation North and South, and the other for East and West. An important note is to maintain the prototypes according to the orientation, and not to rotate them. In the case of needing some specific angle of orientation, a different proposal might be needed.

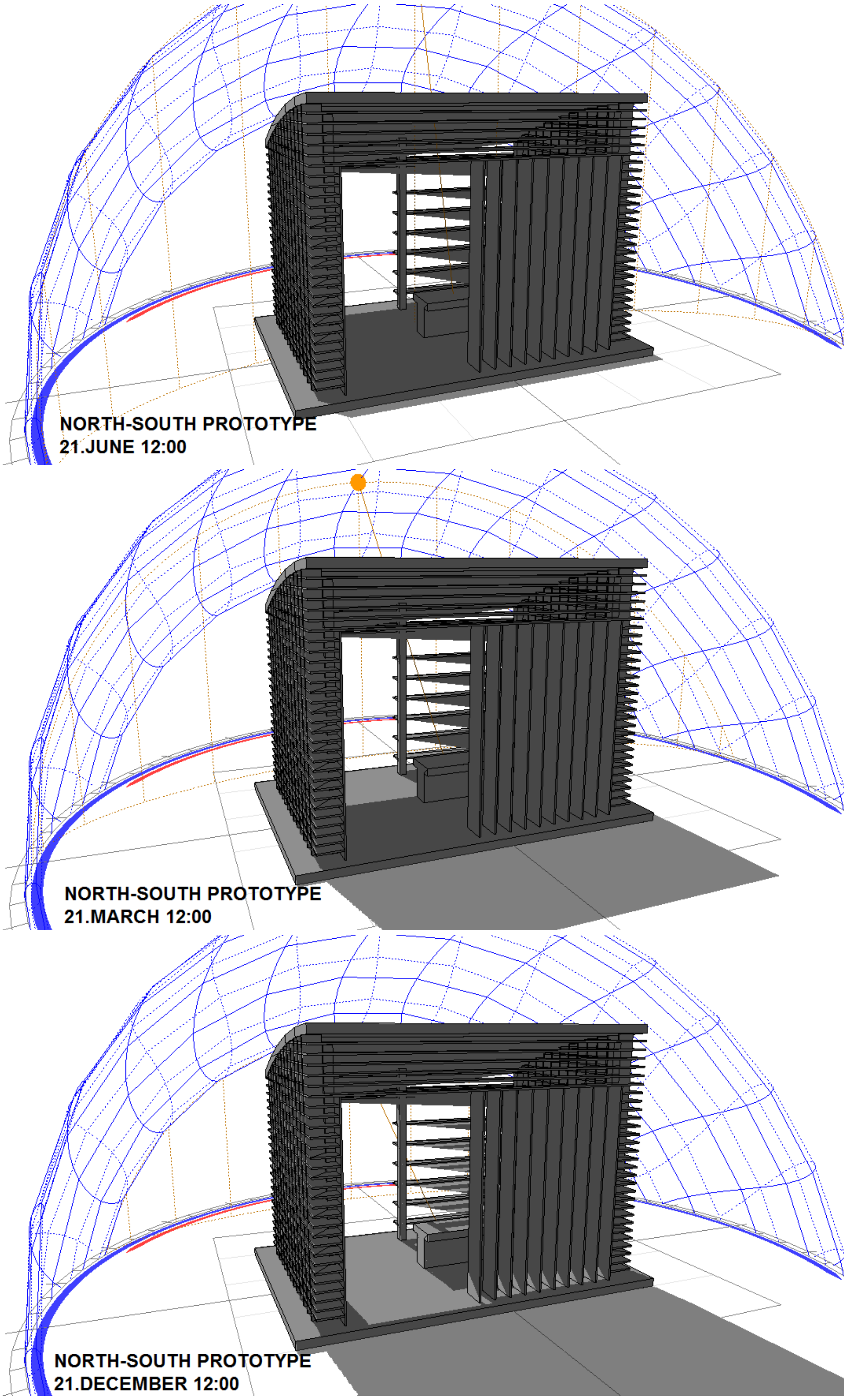


Figure 62. Bus stop proposal, shade analysis, North-South Prototype

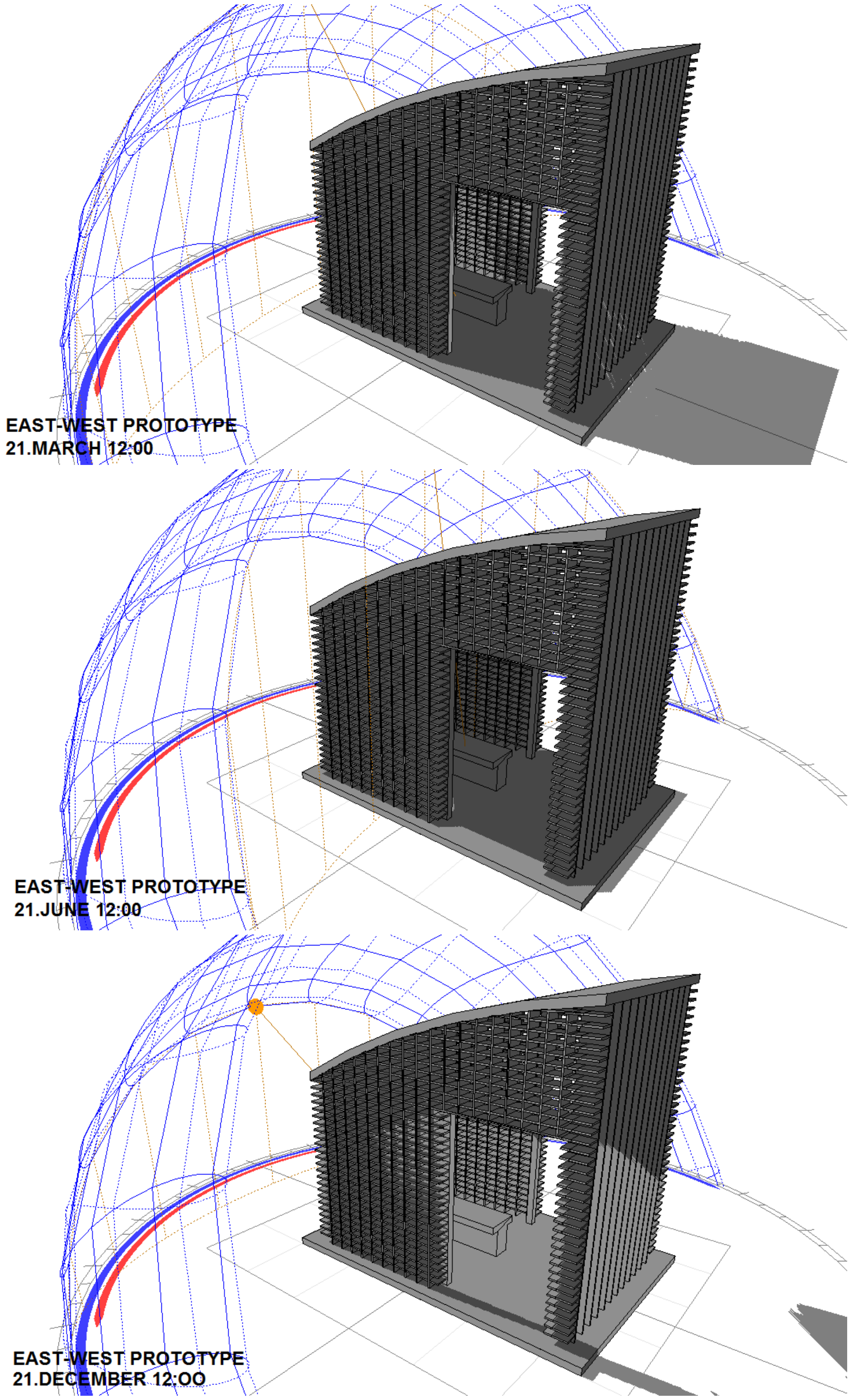


Figure 63. Bus stop proposal, shade analysis, East-West Prototype

These design proposals seek to accommodate a proper design according to the weather conditions and sun path analysis performed. In order to apply them in other location, the design would need to be adapted to the specificity of every region.

Along with the need to cover up from excessive insolation, it is very much recommended to look for alternatives of construction materials, where those that are originated from the location are typically more suitable to cope easily to the climate conditions.

Together with the traditional local construction materials, another important topic is to be taken into account: Vegetation. It is crucial specially in places with arid climates, due to the low need of irrigation.

Another important issue to keep in mind is, as mentioned before, the increasing number of cyclists that there are in Hermosillo. These usually gather over a hundred people to ride through the city, and, because of the high temperatures, they usually cycle at night, when climate conditions are milder.

Therefore, it is important to consider improving conditions for bicyclists, through infrastructure according to their needs, giving people the opportunity to commute in a safer, easier, kinder, more comfortable and sustainable manner.

Regarding design for extreme climate conditions, I contacted Jeff Speck via twitter to ask personally if he had any special proposal or recommendations for working with cities with hot climate, and he answered: “Just the obvious. Codes must require continuous trees and/or awnings. I'm doing this in Tampa” (SIC). (Speck, 2016)

CHAPTER VII. **DESIGN OF INTERVENTIONS**

As seen in previous chapters, there is a high demand for better mobility in downtown Hermosillo, which is conditioned by the weather, therefore a proposal for improving this is needed to be implemented.

VII.1.CONDITIONS AND OBJECTIVES

The main objective of this approach is studying the flow of people and meet their mobility needs. This includes the promotion of using modes of transportation others than the car. Therefore, walking, cycling and using public transport are highly encouraged.

This is especially important for an area as significant as downtown. In the case of Hermosillo, most of the users already go to the place by bus, despite the limitations given by the large space given to motorized vehicles.

A proper proposal for the area of study needs to take into account: temperature, insolation, humidity levels, wind, orientation and location, as well as urban furniture, transit requirements, vegetation, hardscape, construction materials and shading needs, in order to be properly designed according to the local conditions.

VII.2.SELECTION OF LOCATIONS

The public space of downtown Hermosillo was analyzed, describing the components of every street in the area (see table 6) to use as baseline for the design.

Table 6. Description of every street in the study area

DOWNTOWN HERMOSILLO							
Street	Orientation	Width[13]	Car traffic		Land use[14]	Pedestrian demand[15]	Feasibility to pedestrianize[16]
			Function	Demand			
Blvd. Luis Encinas	E-W	37.35	Arterial	High	Commercial	Low	Low
Blvd. Luis Encinas	SE-NW	26.70	Arterial	High	Commercial	Low	Low
Niños Héroes	E-W	15.74	Local road	Low	Mix	Low	Low
Oaxaca	E-W	13.49	Local road	Low	Commercial	Low	Medium
Sonora	E-W	11.09	Local road	Low	Commercial	Low	Medium

[13] Width considers the entire profile of the street, from façade to façade, including sidewalks and street. For design proposes the most critical value (narrowest street) was used. Information provided by IMPLAN Hermosillo.
[14] Personal observation, as shown in figure 29.
[15] Personal observation. Streets with many clothing boutiques and shoe stores generally attract more customers.
[16] Estimated according to the combination of high pedestrian demand, low car traffic and commercial land use.

Luis Donaldo Colosio	E-W	14.21	Collector	Medium	Commercial	Medium	Medium
Dr. Noriega	E-W	14.49	Collector	Medium	Commercial	High	High
Morelia	E-W	8.14	Local road	Medium	Commercial	High	High
Monterrey	E-W	12.31	Local road	Medium	Commercial	High	High
Plutarco Elías Calles	E-W	11.86	Local road	Medium	Commercial	High	High
Serdán	ENE-WSW	13.90	Local road	Medium	Commercial	Medium	Medium
Chihuahua	E-W	9.04	Local road	Low	Housing	Low	Low
Arista	WNW-ESE	8.80	Local road	Low	Housing	Low	Low
Obregón	E-W	20.08	Local road	Low	Commercial	Medium	Medium
No Reelección	E-W	10.39	Local road	Low	Mix	Medium	Medium
Rosales	N-S	20.17	Arterial	High	Mix	Medium	Low
Pino Suárez	N-S	12.39	Arterial	High	Commercial	Low	Low
Yáñez	N-S	10.41	Collector	High	Mix	Low	Medium
García Morales	N-S	10.09	Local road	Low	Commercial	Low	Medium
Garmendia	N-S	9.07	Collector	High	Mix	Medium	Medium
Guerrero	N-S	8.86	Local road	Medium	Commercial	Medium	High
Mariano Matamoros	N-S	14.80	Collector	Medium	Commercial	High	High
Benito Juárez	N-S	10.74	Collector	Medium	Commercial	High	High
Horacio Soria	N-S	8.12	Local road	Medium	Commercial	Low	Medium
Jesús García	N-S	13.90	Local road	Medium	Mix	Low	Low
Callejón Félix Soria	N-S	14.77	Local road	Low	Commercial	Low	Low
Mariano Abasolo	N-S	5.85	Local road	Low	Commercial	Low	Low
Callejón Borunda	N-S	4.31	Local road	Low	Housing	Low	Low
Del Cerro	N-S	9.90	Local road	Low	Housing	Low	Low

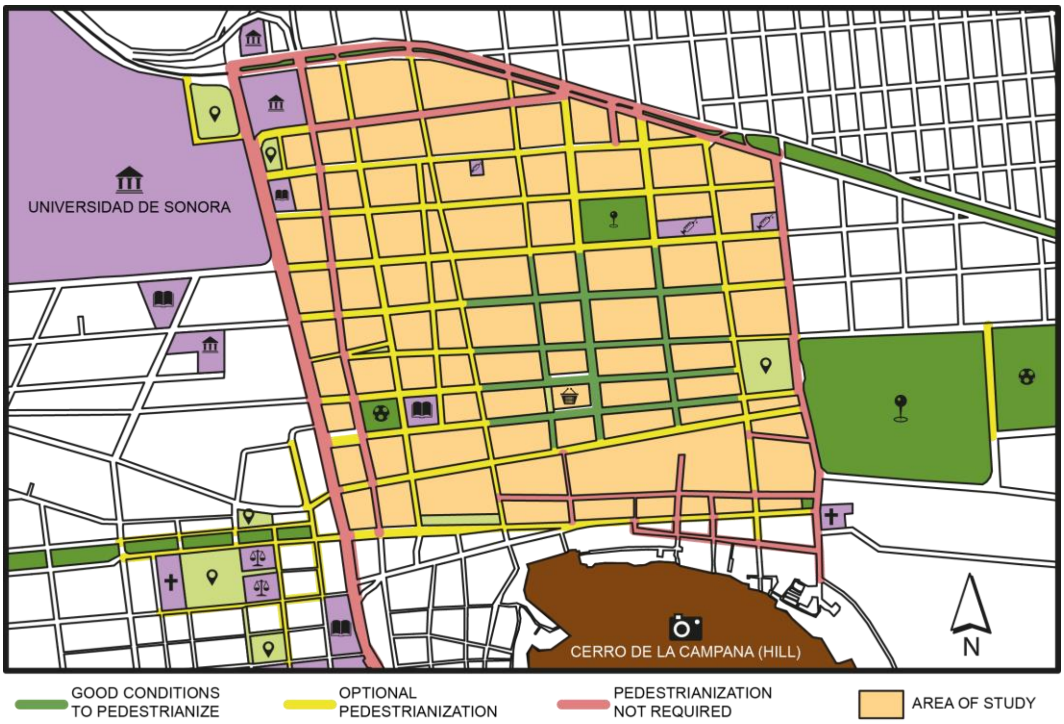


Figure 64. Feasibility of downtown's streets to pedestrianize

Figure 64 shows a preliminary map of streets to pedestrianize, according to the information shown in table 6. This map works as reference point to generate a more complex proposal, also taking into account road traffic, public transportation routes, points of interest, pedestrian behavior and desire paths.

According to the use of the public space, every street was categorized, helping to analyze the possible actions to perform for the design intervention.

Due to the current occupation of the streets, a few parking lots could be affected due to the restrictions to apply in some roads. Nevertheless, these areas could also be used to create new uses or activities. Some of the options are creating recreational areas, using the space for constructing new buildings and even making new areas of commerce that don’t require much investment, like spaces for food trucks, helping to produce new livable places.

VII.3.SELECTION OF DESIGN ELEMENTS

For this proposal, a set of design elements have been taken, including composition of complete streets, pedestrian streets, bike lanes, bike parking, prototype of bus stops according to every orientation, endemic vegetation like “Palo Verde Tree” (*Cercidium microphyllum,* which is a deciduous tree, allowing sun beams to go thru in winter), awnings, urban furniture, etc.

The streets where the bus paths go through have been restricted to some specific streets (Yañez, Garmendia, Dr. Noriega, Jesús García, and a section of the streets Matamoros and Juarez). Bus stops must be located inside the area every three blocks, in order to ease the arrival of people to their destination, to minimize exposure to the sun.

Ave. Serdán has been connected to the northern lane of Blvd. Hidalgo, creating a link between the Civic Downtown (Cathedral, Central Plaza and Government buildings) and the Shopping Downtown. This street is intended to be for bus and bikes only, to work as a southern hub for public transportation, connecting by bus to the rest of downtown area with the streets Yañez, Garmendia and Jesús García.

Some of the mayor streets have also been designed with wider sidewalks on the south, which helps to receive shade from the buildings.

As said before, the classical TOD designed needs to be revised to be adapted to different locations, to be able to take advantage of the local conditions and be protected from harsh situations. That is the case for locating trees or other shading elements, which, depending on the latitude, project shadows in some specific angles. In order to use this for our advantage, a different set of trees and positions should be utilized (see figure 65).

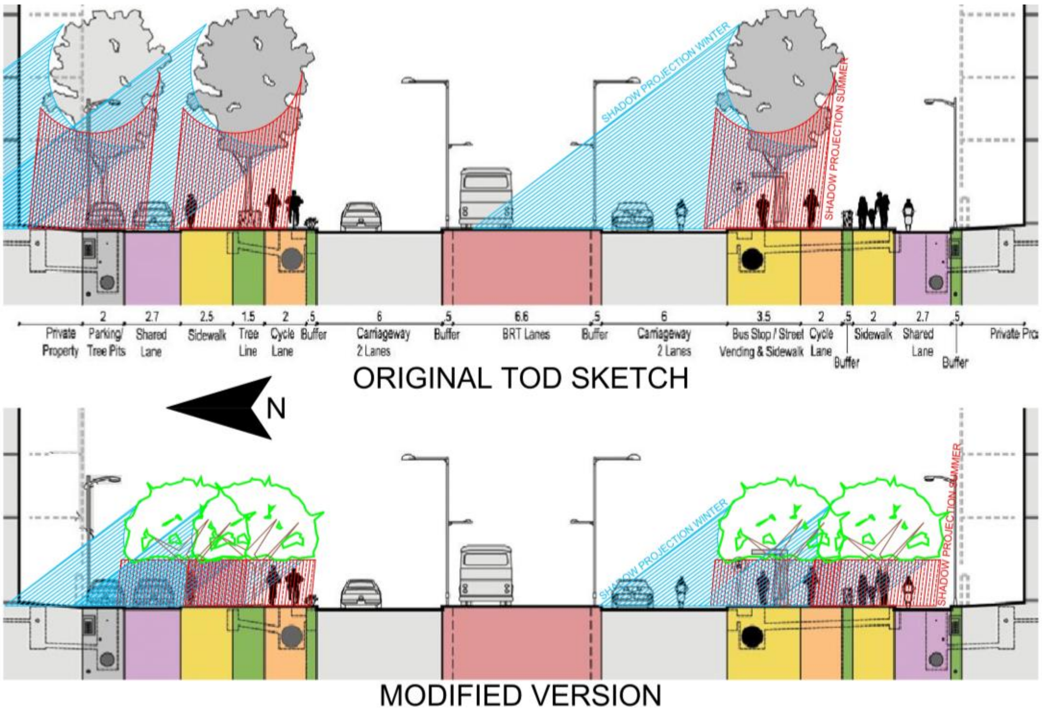


Figure 65. Revamp of classical TOD sketch for Hermosillo, Sonora, Mx.[17]

VII.4.PROPOSAL

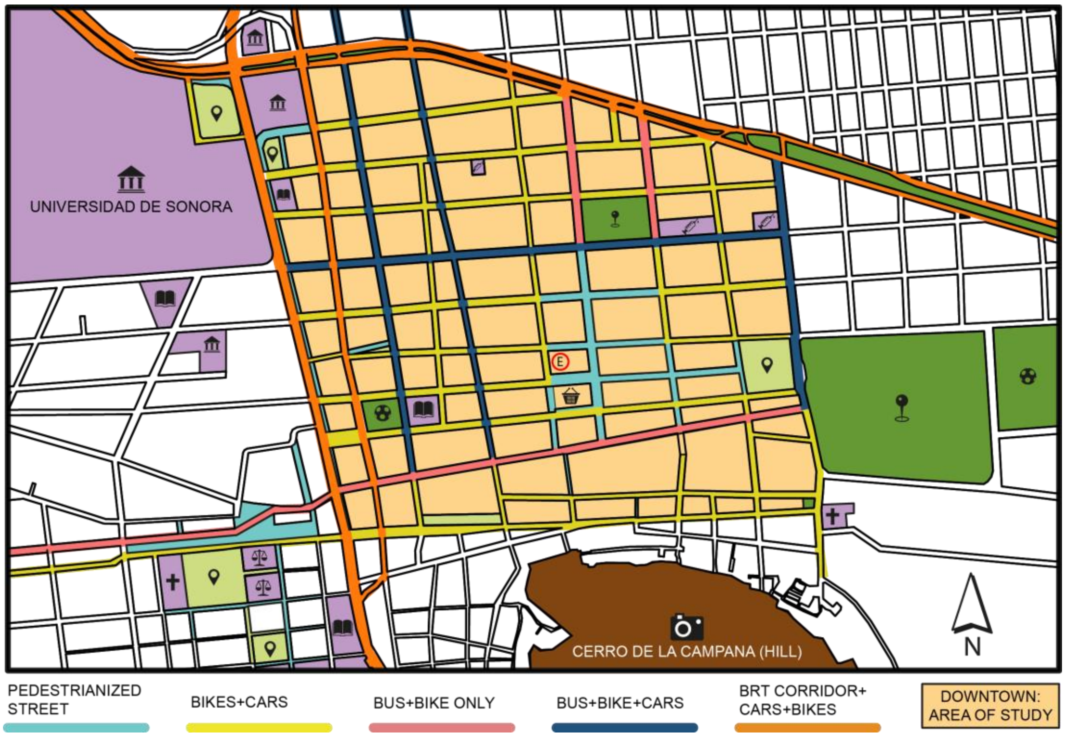


Figure 66. Map of proposal for downtown Hermosillo

[17] Modified from ITDP (2011)

Figure 67. Current status of Blvd. Luis Encinas. View from west to east. Source: Google Street View, 2016

Figure 68. Proposal of BRT station in Blvd. Luis Encinas. View from west to east

Figure 69. Proposal of BRT station in Blvd. Luis Encinas. View from North-east

Figure 70. Current status of intersection between Matamoros and Monterrey. View from north to south

Figure 71. Proposal of pedestrianized intersection Matamoros and Monterrey. View from north to south

Figure 72. Current status of Ave. Monterrey. View from west to east

Figure 73. Proposal of pedestrianization of Ave. Monterrey. View from west to east

Figure 74. Current status of Street Matamoros. View from south to north

Figure 75. Proposal of pedestrianization of Street Matamoros. View from south to north

Figure 76. Current status of Ave. Monterrey, next to the Municipality Market. View from west to north

Figure 77. Proposal of pedestrianization of Ave. Monterrey, next to the Municipality Market. View from west to north

Figures 78 to 87 show a set of design proposals of the components of the streets from the area of study.

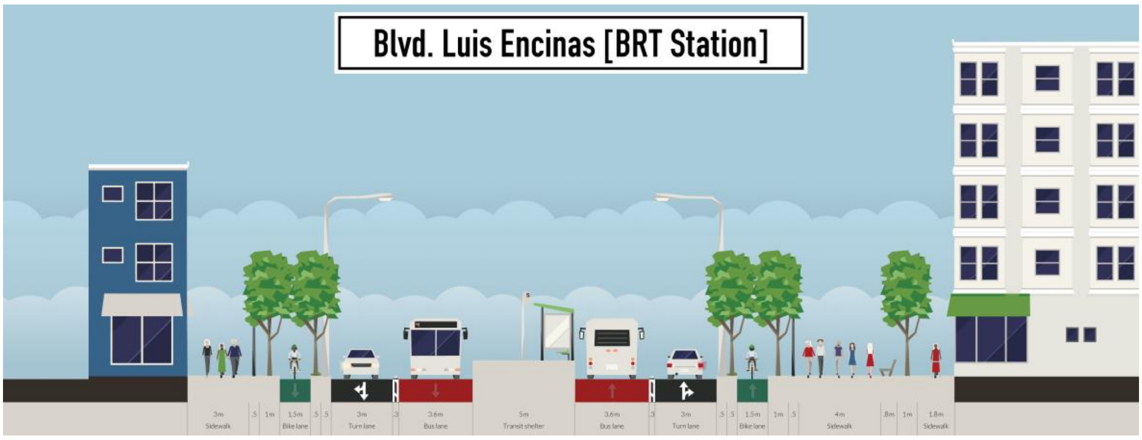


Figure 78. Proposal of BRT station in Blvd. Luis Encinas. Section cut

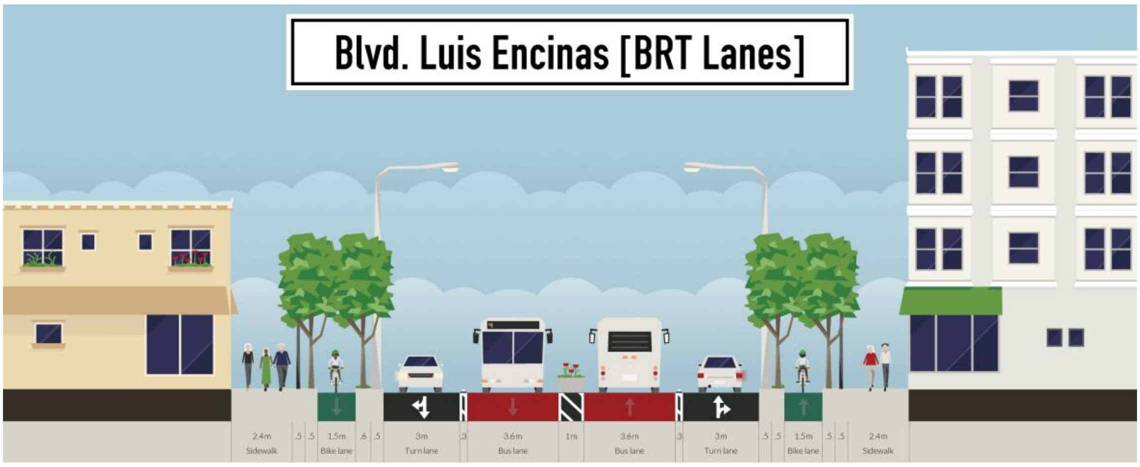


Figure 79. Proposal of BRT lanes in Blvd. Luis Encinas. Section cut

Figure 80. Proposal of pedestrianization on Ave. Monterrey. Section cut

Figure 81. Proposal of intervention to Ave. Serdán. Section cut

Figure 82. Proposal of intervention to Ave. No Reelección. Section cut

Figure 83. Proposal of intervention to Ave. Colosio. Section cut

Figure 84. Proposal of intervention to Street Yañez. Section cut

Figure 85. Proposal of intervention to Street Garmendia. Section cut

Figure 86. Proposal of intervention to Street Juárez. Section cut

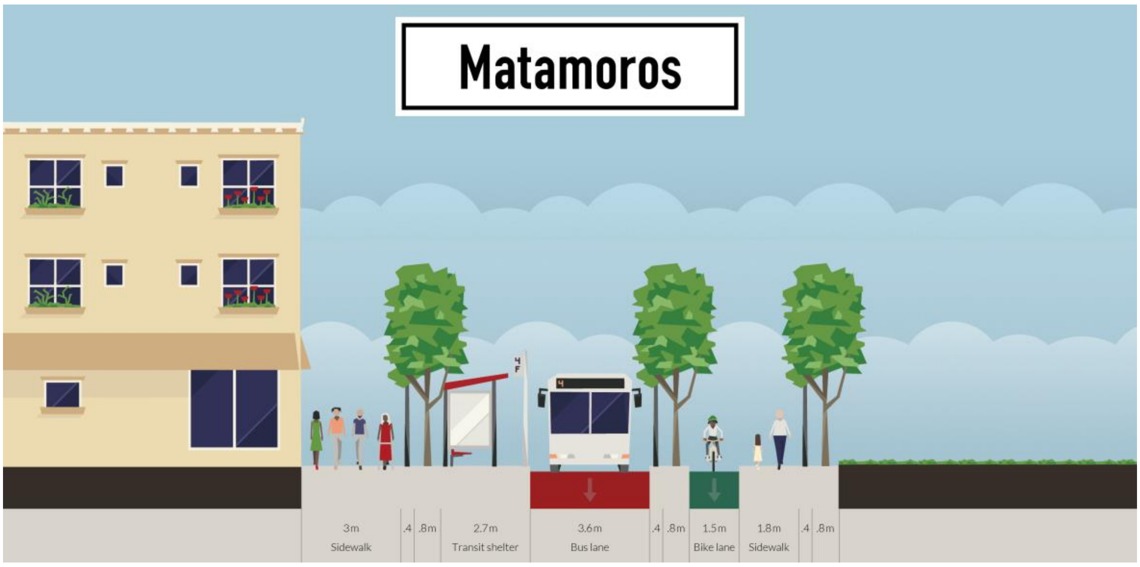


Figure 87. Proposal of intervention to Street Matamoros. Section cut

From this set of figures, it is derived the proposal of revamping the streets in downtown Hermosillo, the area of study. These designs show how the components of the streetscape can be reorganized in order to provide better conditions for walking, cycling and using public transportation.

The section cuts of avenues (figures 78 to 83) are displayed with the north oriented to the left, while the streets (figures 84 to 87) are oriented facing north (west to the left, east to the right).

Because of the altitude of the sun trajectory, avenues are designed with a wider sidewalk to the south, this helps to use the buildings to provide shade.

In the case of streets, these are designed thinking in placing a set of trees in every side of the road whenever the width of the street gives the possibility. In the case of narrower streets like Garmendia (figure 85) awnings shall be implemented to provide shade.

Due to limitations of the system used, it was not possible to place more than one purpose in every part of the section cut, nevertheless in some cases, like space for bus stations, a set of trees, public lighting and bollards must be considered.

Finally, figure 88 shows a map with bus stops and BRT stations located in the area of study and its surroundings. These stations and stops are placed at a maximum distance of about 300 meters, to provide the users a shorter walk to reach their destination, in order to reduce insolation.

Figure 88. Map of proposal of Bus and BRT paths and stations

CHAPTER VIII. SUMMARY

As stated in the objectives, the main purpose of the thesis was to design a non-motorized mobility scheme that is specially designed for warm-climate cities, this was made by taking the study case of the city of Hermosillo, Sonora, México, which, due to its climatic characteristics, mobility can be an issue, therefore it is of high importance to procure the best approach possible in favor of the population, according to the location.

It was characterized the main obstacles that pedestrians and bicyclists have to cope are mainly lack of proper infrastructure, that allow them to move freely in the city. This is a typical issue found in developing countries, where in many occasions there is almost no budget designated to pedestrians and bicyclists.

Therefore, most of the expenses that are meant for mobility are given to the cars, creating new roads and maintaining the infrastructure for automobiles. Because of the facilities given to cars, the use of automobiles is commonly increased, causing social, economic and environmental issues, like health problems, inequity in the use of the public space, pollution, CO2 emissions and high externalities that we all end up paying.

This is why it is highly promoted the switch cities towards Transit Oriented Development, which is an urban model designed around public transport, allowing people to enjoy a diversity of land uses, as well as favoring social interaction through active and safe public spaces.

Giving the seven elements of TOD, the main focus of this work was the first topic ‘Non-motorized mobility”. This helps to promote a better use of the public space, due to the promotion of walking and cycling as a method of transport, which, along with high-quality public transportation, helps to provide more public space for people and their activities, instead of using plenty of space with an automobile to move a single person.

With the proposal it was intended to provide an alternative for downtown Hermosillo, which is a highly commercial area, with many shops and places for people to acquire clothing, as well as obtaining some services like hairstyling, eating and doing some recreational activities.

This project also planned to reach the topics promoted by experts like Jeff Speck, Jan Gehl and Janette Sadik-Kahn. They all promote the creation of livable spaces for people to enjoy, specially meant to be walked.

In the fieldwork a set of activities were made, including observations, interviews, a tour around the study area with a group of volunteers and compilation of photographic evidence via a Photovoice exercise and personal documentation.

Specifically addressing the climate conditions to cope to, an analysis of the local settings of the area of study was made, including general weather data, as well as analysis of sun path. This helped to get a general idea of the climatic elements to take into account then designing the proposal.

Combined with the local weather analysis, the area of study was characterized, defining the extents, the conditions giving in the zone and a review of some of the approaches that the institution in charge of urban planning in Hermosillo has presented.

Resulting from the analysis performed, it was presented the design schemes to apply in the area, which were put into context using the actual information of the zone, presenting a series of images that illustrate the proposal made specifically to the area.

After doing the proposal, and due to the research limitations on time and extension, some topics could be recommended to keep on the research. For instance, to continue with the specifications necessary to complete the project to a deeper level, like details on construction materials, vegetation and elements to improve the mobility for pedestrians and bicyclists at night.

Likewise, the completion of the project could also be addressed as a consultancy project, helping to connect the rest of the city through improvement in streets, public spaces and efficient public transportation systems.

To stakeholders it would be recommended to foment research on urban topics that are meant to produce spaces in the cities that are more livable, at eye level, to be able to enjoy our urban environments, financing investigation through the implication of specialist, as well as the community, in decision making, with settings like multimodal transportation and alternative modes of transit, combining walking, cycling and different modes of public transit, together developing an integrated system.

CONCLUSIONS

It is of great relevance encouraging walking and cycling in cities, especially in those with extreme climates, where commuting requires an extra effort due to meteorological conditions.

But this won't be achieved just by advertising the benefits of these activities, it is needed to apply specially designed interventions, because the general designs might not be properly applicable in every context, therefore a research on finding specific needs and strategies is needed in many research topics, especially those produced in developed countries, where the effects of weather conditions are not such a big obstacle when performing activities on public space.

Therefore, it is important for hot climate cities to consider incorporating elements that provide shade in the design of urban and architectural spaces in general in our city, needed to act more comfortably.

This design plan has intended to produce a specifically mobility scheme, where a large range of characteristics are taken into account, considering climate conditions, urban components, transit requirements and users' needs.

This study was made in an area with a high development index, nevertheless the context of the city, located in a developing country, in a location that is far away from the capital city, where most of the budget, incentives and eyes of the population are focused on.

Seeking to create a city with high Transit Oriented Development is important to produce more habitable urban scapes, and this is not only achieved by performing a desk-research, it is important to get to know well the area to be analyzed, as well as including the users and their needs in the process of decision taking, in order to improve non-motorized mobility.

"It's possible to change your streets quickly, it's not expensive, it can provide immediate benefits, and it can be quite popular. You just need to re-imagine your streets, their hidden in plain sight." (Sadik-Kahn, 2013)

“The *Walkable City* is a city that puts people first and shapes itself in accordance to its citizens’ needs and desires.” (ARUP, 2016)

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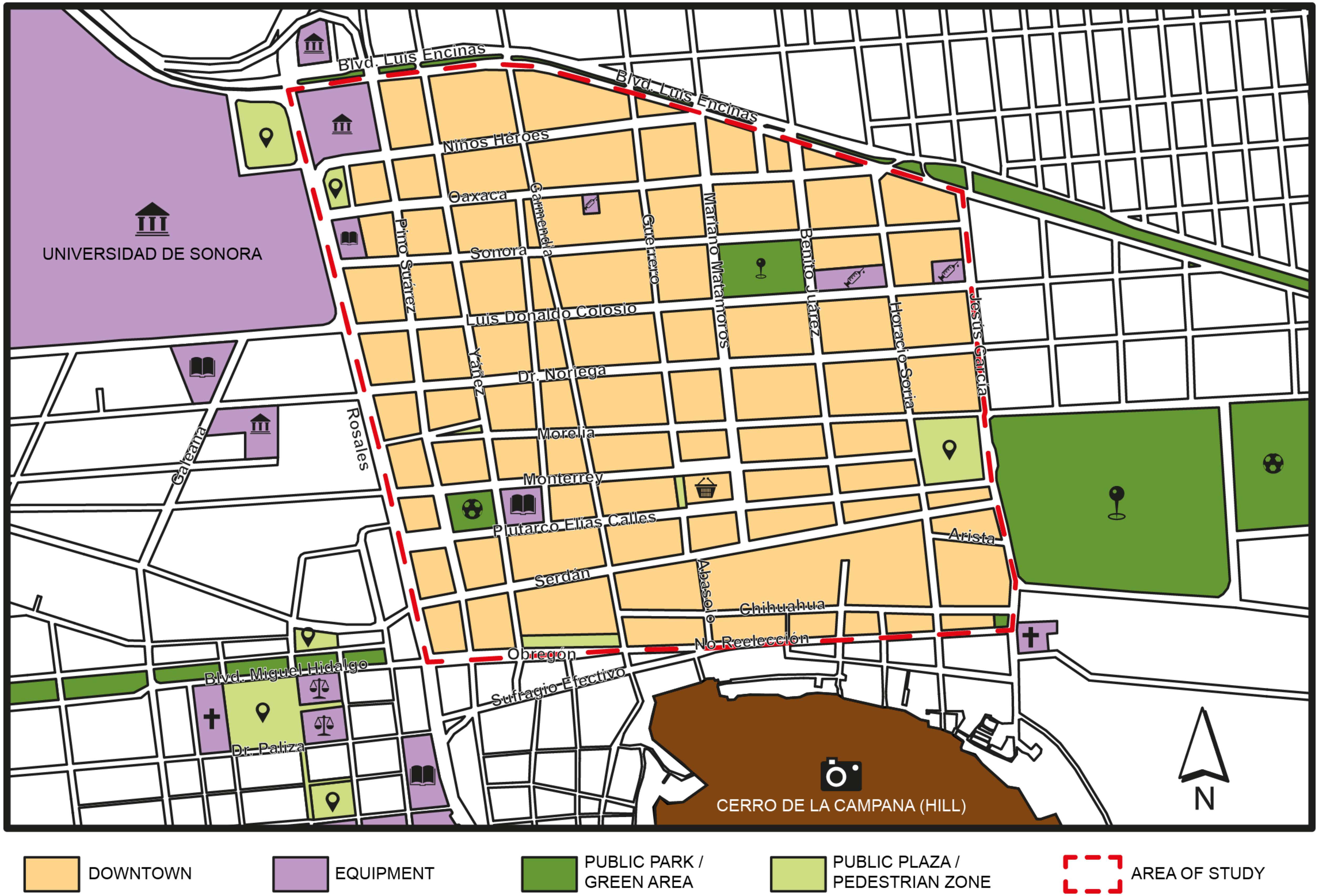
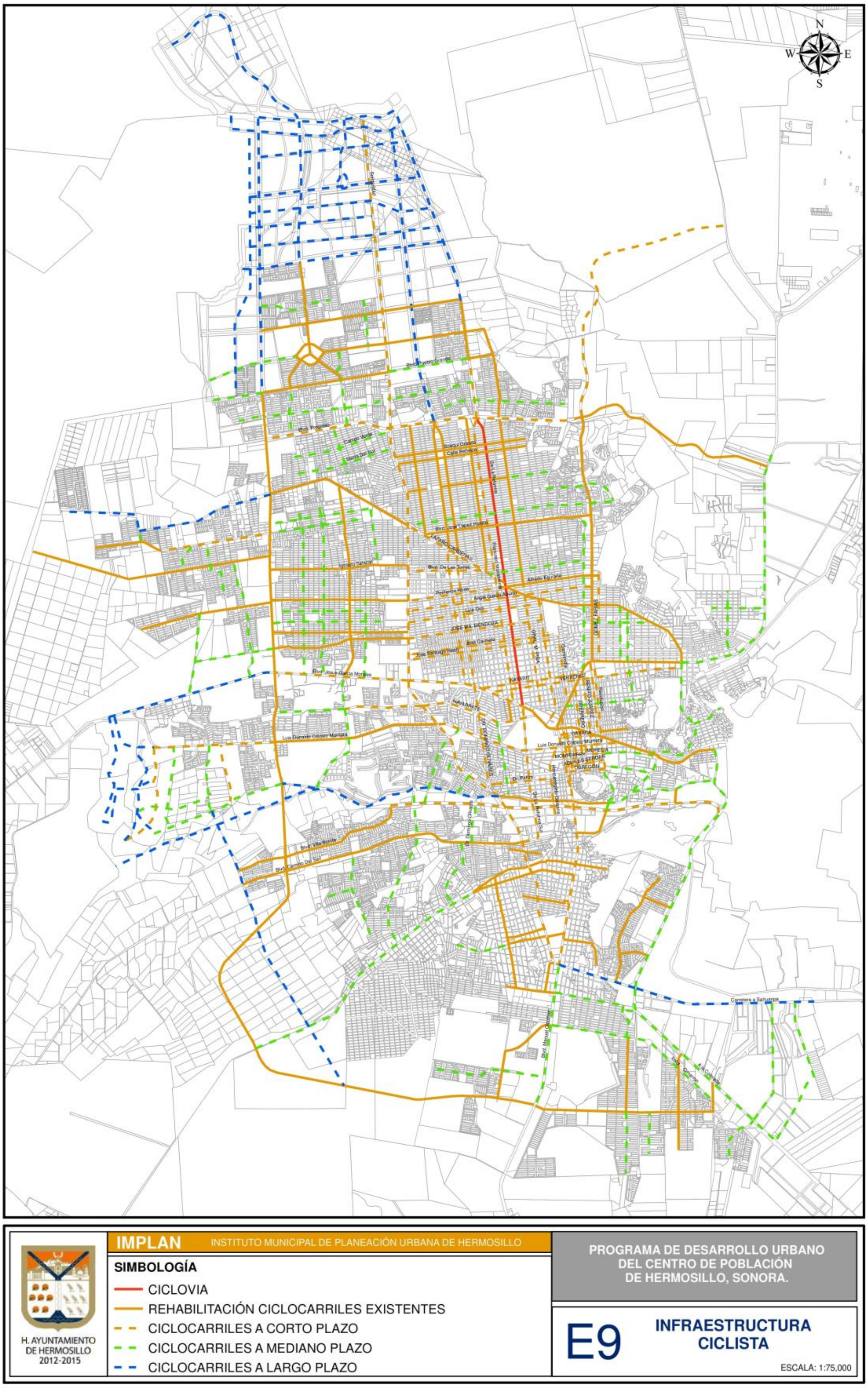
ANNEXES



Annex A. Map of downtown Hermosillo



Annex B. Bicycle infrastructure map. Source: IMPLAN Hermosillo, 2014