



Does Panama City's Street Network Support a Pedestrian- and Transit-Oriented Mobility System?

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I. Abstract

The Panamanian government is investing unprecedented sums into the public transit system in order to reduce concerns over mobility, the environment and social exclusion. However, the process of urban expansion in the Panama City Metropolitan Area has not resulted in the provision of a street network that support a pedestrian- and transit-oriented mobility system. The purpose of this report is to formulate a series of changes to the system that governs the construction of the street network in a way that contributes to the efficiency of the regional public transportation system. To do this, five representative neighborhoods (Arraiján Central, Loma Cobá, Villa Lucre, 24 de Diciembre and Nuevo Tocumen) were evaluated through a series of spatial analyses. An on-site visit was also performed to complement the spatial analysis in the neighborhoods of Nuevo Tocumen and 24 de Diciembre. From the analysis it was revealed that the street network in Panama is deficient because it does not provide sufficient amount of arterial roads and neighborhoods are characterized by poor street connectivity both internally and externally. Differences in connectivity were found between formally built developments and organic informal settlements. Based on the findings, a series of corrective and preventative policy recommendations are presented that, if followed, will lead to an overall more connected, flexible and pedestrian- and transit-oriented street network in the Panama City metropolitan area.

Résumé

Le gouvernement panaméen investit des sommes sans précédent dans le système de transport en commun afin de répondre aux préoccupations concernant la mobilité, l'environnement et l'exclusion sociale. Cependant, le processus d'expansion urbaine dans la région métropolitaine de Panama n'a pas abouti à la mise en place d'un réseau routier qui soutient un système de mobilité axé sur les piétons et les transports en commun. Le but de ce rapport est d'élaborer une série de modifications au système régissant la construction du réseau routier d'une manière qui contribue à l'efficacité du système régional des transports en commun. Pour entreprendre ceci, cinq quartiers représentatifs (Arraiján Central, Loma Cobá, Villa Lucre, 24 de Diciembre et Nuevo Tocumen) ont été évalués à travers une série d'analyses spatiales. Une visite sur place a également été effectuée pour compléter l'analyse spatiale des quartiers Nuevo Tocumen et 24 de Diciembre. De l'analyse, il a été révélé que le réseau routier au Panama est défaillant car il ne fournit pas une quantité suffisante de routes artérielles et les quartiers se caractérisent par une mauvaise connectivité des rues à la fois de l'intérieur et de l'extérieur. Des différences dans la connectivité ont été constatées entre les développements construits formellement et les établissements informels développés organiquement. Sur la base des résultats, une série de recommandations politiques visant à orienter des mesures correctives et préventives sont présentées que, si suivi, conduiront à un réseau routier globalement plus connexe, flexible et axé sur les piétons et les transports en commun dans la région métropolitaine de Panama.

Resumen

De una manera sin precedents, el gobierno panameño está invirtiendo sumas en el sistema de transporte público para reducir las preocupaciones sobre la movilidad, el medio ambiente y la exclusión social. Sin embargo, el proceso de expansión urbana en el Área Metropolitana de la Ciudad de Panamá no ha dado lugar a la provisión de una red vial que apoye un sistema de movilidad orientado a peatones y tránsito público. El propósito de este informe consiste en formular una serie de cambios al sistema que rige la construcción de la red de calles de una manera que contribuya a la eficiencia del sistema de transporte público regional. Para ello, se evaluaron cinco barrios representativos (Arraiján Central, Loma Cobá, Villa Lucre, 24 de Diciembre y Nuevo Tocumen) a través de una serie de análisis espaciales. También se realizó una visita in situ para complementar el análisis espacial en los barrios de Nuevo Tocumen y 24 de Diciembre. Este análisis reveló que la red vial en Panamá es deficiente debido a que no proporciona una cantidad suficiente de calles arteriales y que los barrios se caracterizan por la mala conectividad de la calle tanto interna como externamente. Se encontraron diferencias en la conectividad entre los proyectos de construcción formales y los asentamientos informales orgánicos. Basados en estos hallazgos, una serie de recomendaciones correctivas y preventivas se ofrecen para producir una red de calles más conectadas, flexibles y orientadas a peatones y transporte público en el área metropolitana de la Ciudad de Panamá.

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III. Table of Contents

I.	ABSTRACT	II
II.	ACKNOWLEDGEMENTS	III
III.	TABLE OF CONTENTS	IV
IV.	LIST OF FIGURES	VII
V.	LIST OF TABLES	IX
CHAPTER 1: INTRODUCTIONS		1
CHAPTER 2: CONTEXT AND LITERATURE REVIEW		5
2.1	Spatial Context	5
2.2	Historical Morphological Analysis	6
2.2.1	Geographic and Environmental Constraints	6
2.2.2	Demand for land by firms and households	6
2.2.3	Policy Constraints that govern land use and spatial interactions in the city	8
2.3	Literature Review	10
2.3.1	History and Rationale of the Modern Street Network	11
	<i>a. The Gridiron</i>	11
	<i>b. Curvilinear Street Design and Street Hierarchy</i>	14
	<i>c. Standardization</i>	16
2.3.2	Alternative Street Network Design	18
	<i>a. Street Connectivity</i>	18

<i>b. Tools to achieve greater street connectivity</i>	21
2.3.3 Street Network Design in the Context of Rapid Urban Development	23
2.3.4 Summary	26
CHAPTER 3: METHODOLOGY AND DATA	28
CHAPTER 4: ANALYSIS	31
4.1 Introduction to the Five Representative Neighborhoods	31
4.1.1 Arraiján Central & Loma Cobá	34
4.1.2 Villa Lucre	35
4.1.3 24 de Diciembre & Nuevo Tocumen	36
4.2 Spatial Analysis	39
4.2.1 Evaluation of Arterial Street Network	39
4.2.2 Evaluation of Block Size	47
4.2.3 Evaluation of Pedestrian Route Directness	55
4.2.4 Evaluation of Internal Street Connectivity	58
4.2.5 Issues Raised	60
4.3 On-Site Visit	62
4.3.1 Purpose	62
4.3.2 Findings	63
CHAPTER 5: POLICY RECOMMENDATIONS	73
5.1 Corrective Policies	74

5.2	Preventative Policies	76
CHAPTER 6: CONCLUSION		81
VI.	BIBLIOGRAPHY	88

IV. List of Figures

2.1	Spatial dimensions of Panama's City's urban extent	5
2.2	Illustration of 30-degree geographic constraint on Panama City Growth	6
3.1	Current state of Line 2 construction near Nuevo Tocumen	28
3.2	Master Plan of the completed fixed-rail metro network	28
3.3	Reference Map: Five Representative Neighborhoods	30
4.1	Typological Map of street network patterns throughout the AMP	32
4.2	Pattern of development on the eastern sector of the AMP	33
4.3	Urban extent growth of Arraiján Central and Loma Cobá (1986 – 2017)	34
4.4	Informal settlement growth in Arraiján (2009 – 2016)	34
4.5	Physical growth of Villa Lucre	35
4.6	Extension of collector road to Corredor Norte	36
4.7	Three properties purchased by government from landowners	37
4.8	Original perimeter of the property on which the airport was built	38
4.9	Portion of land sold to private buyer	38
4.10	Physical growth of 24 de Diciembre and Nuevo Tocumen	38
4.11	Arterial street network and expressway network in the AMP	40
4.12	Evolution of the arterial street and expressway network in the eastern portion of the AMP	41
4.13	Portion of the AMP's urban extent within walking distance (625) of an arterial street	43
4.14	Hypothetical Spacing of arterial roads in the five representative neighborhoods	44
4.15	Number of intersections within 1.6 km in the five representative neighborhoods	45

4.16	Evolution of block size in the AMP – Part 1	48
4.16	Evolution of block size in the AMP – Part 2	49
4.17	Variation of block size in the five representative neighborhoods	50
4.18	800-meter catchment area of metro stations for the five representative neighborhoods	51
4.19	800-meter catchment area of transit stations centered in theoretical grids	52
4.20	Results of Figures 4.18 and 4.19	53
4.21	Example of the deficiency of the street network caused by large blocks (Nuevo Tocumen)	54
4.22	Example of the deficiency of the street network caused by large blocks (Nuevo Tocumen)	55
4.23	Pedestrian Route Directness ratio for the five representative neighborhoods	57
4.24	Pedestrian Route Directness ratio for two theoretical street networks	57
4.25	Link-to-node ratios of a 1km section in the five representative neighborhoods	59
4.26	Areas of poor connectivity in 24 de Diciembre and Nuevo Tocumen	61
4.27	On-site reference map for Nuevo Tocumen and 24 de Diciembre	63
4.28	Location of photos from the on-site visit	64
4.29	Barriers to connectivity in Nuevo Tocumen and 24 de Diciembre	66
4.30	Evidence of residents adapting to poor connectivity caused by the Megamall in Nuevo Tocumen	67
4.31	Various photos of issues regarding connectivity in Nuevo Tocumen and 24 de Diciembre	69
4.32	Various photos of rivers in 24 de Diciembre, poor connectivity and newly built informal settlements	72
5.1	Figure depicting the link-to-node ratio when including dead-ends or not	77
6.1	Location of Porta Norte	83
6.2	Porta Norte Master Plan	84
6.3	Porta Norte block size variation, links, nodes and external connectivity	86

V. List of Tables

2.1	Advantages and disadvantages of the gridiron	13
2.2	Advantages and disadvantages of increased street connectivity	20

Chapter 1: Introduction

Among challenges facing the Panama City Metropolitan Region (AMP), mobility is a persistent concern. Public transport users living outside the central area of the AMP spent on average four hours commuting per day in 2011. In comparison, those traveling by car can spend between 40 and 48 minutes, five to six times less (Espino et al. 2011). This is more alarming when presented with the fact that only 39% of households in the Panama Province own vehicles (Plan de Acción, 2015). More recently, the PIMUS transit study (R. Panamá, 2015) revealed that, on average, private and public transit users throughout the AMP spend over one hour per trip during rush hour. This is especially concerning because the study found that rush hour was actually a three-hour period in the morning and a four-hour period in the evening. This is a clear indicator of the inefficacy of the mobility system as a whole. At the moment, the government is investing unprecedented sums to improve the public transport system by “modernizing” city buses and constructing a new fixed-rail metro system. In 2010, construction of Line 1 of the Panama City rapid transit metro was commenced and was completed in 2014. Now, Line 2 is underway with an expected inauguration sometime in 2018 (Panama, 2016). Overall, the process of urban expansion in Panama has not resulted in the provision of a street network that supports a pedestrian- and transit-oriented mobility system.

The pattern of urban expansion in Panama has been deficient because it does not provide a well-connected network or an adequate number of appropriately spaced arterial roads (Tyler 2002; 2015). This has been the result of rapid urban population growth, failed urban planning, state retrenchment in housing and a deficiently regulated real estate and construction industries. Without modifications to the urban structure, as well as regulations that govern their construction, benefits of the new public transportation system will be limited. Sustainability, quality of life and competitiveness of the urban region depends, to a large extent, on the success of the public transportation system; therefore, it is dependent on a street network that prioritizes pedestrians over the automobile. Furthermore, the Metropolitan Area of Panama is expected to grow by 1 million people by 2050. Knowing this, it is imperative that provisions are made and regulations enforced that will guarantee a flexible pedestrian- and transit- oriented street network from the beginning.

The purpose of this report is to formulate a series of changes to the system that governs the construction of the street network in a way that contributes to the efficiency of the regional public transportation system. The principal issue to be analyzed is the actual form of the existing road network. The network, especially in more recent times, has primarily been built by private developers or by informal builders or land invaders.

Private developments have abided by current regulations that regulate the street layout for subdivisions. But these regulations do not necessarily guarantee a street layout that encourages pedestrian movement. Similarly, the street patterns resulting from informal land invasions have been built in a piecemeal fashion and are subjected to topographical constraints. Furthermore, no regulations have been implemented that require any sort of connections between developments, so together, these two types of street patterns have resulted in an incoherent and illogical labyrinth of streets. This report is divided into six chapters: introduction, literature review and historical urban morphological analysis, methodology, spatial analysis and on-site visit, recommendations and conclusion.

The historical urban morphological analysis reveals the pattern of urban expansion that has occurred in Panama (Chapter2). The expansion of urban areas is a result of the interaction of three factors: geographic and environmental constraints, demand for land by firms and households and policy constraints that govern land use and spatial interactions in the city (Angel, 2005). The overall conclusion from the historical morphological analysis was that state retrenchment and a loosely regulated construction and real estate industry, along with a rapidly growing and wealthier population and the physical constraints of the Pacific Ocean and the Canal Zone have collectively produced a growing and elongated urban footprint that is increasingly centralized and fragmented, but less compact and dense than in the past. The first section of the literature review is a brief overview of the history and rationale of the modern street network. The second section covers the characteristics of a street network that supports pedestrian activity and transit use. Today there is little consensus on a desirable street network, but it is clear that a high degree of connectivity and small blocks are key to encouraging active transportation. The third and final section of the literature review reveals how street networks in rapidly urbanizing cities are being formed and governed.

While the street grid has been the preferred street network design for centuries, when streets were widened and sterilized, and the private automobile became the principal means of transport, a preference towards curvilinear streets and a prevalence of cul-de-sacs began taking shape. The car was a modern nuisance and an alteration to the street network was seen as a preferred technique to mitigate its negative impact on residential areas. Overtime, the street network became a product of standardized rules based on the concept of street hierarchy. Streets were meant to reflect their function as an access street or movement street. Freeways represented unrestricted movement of traffic with no land access, while at the other end of the spectrum, cul-de-sacs were solely meant for land access. Now, street hierarchy has resulted in an extreme decline of street connectivity and in many ways created neighborhoods and whole cities that are inhospitable to pedestrians and public transportation.

Today, many municipalities are taking action to reverse years of poor connectivity. Design schemes such as Traditional Neighborhood Design and Pedestrian- and Transit-Oriented Design encourage a greater degree of street connectivity than conventional suburban street layouts. Advocates of street connectivity suggest that connectivity offers numerous advantages such as decreased traffic on arterial streets and increase in route directness, while those averse to improving connectivity worry that it will result in increased levels of through traffic on residential streets. Tools to measure and achieve connectivity generally fall into two categories: block size requirements and connectivity indexes, which quantify how well street networks are connected internally and/or externally.

From the third section of the literature review, it was established that a lack of planning for growth has resulted in a deficiency in the arterial road network almost globally. Arterial roads have proven vital for carrying heavier regional traffic, public transit routes, and trunk infrastructure. Since growth in many developing countries does not show signs of curbing, it is proposed that cities take at least a minimalist approach to plan for growth. Angel (2012) suggests that arterial road right-of-ways, should be spaced at 1km intervals, and planned according to population growth estimates and local and historical growth patterns. When an arterial street network is planned, then growth can be managed in an ordered and coherent manner. This puts the city ahead of developers, leading them to develop, instead of following behind and picking up the mess.

Once the literature was sufficiently explored, an informed spatial analysis (Chapter 4) was performed on five representative neighborhoods in Panama: Arraiján Central, Loma Cobá, Villa Lucre, 24 de Diciembre and Nuevo Tocumen. The first two neighborhoods will soon be home to Line 3 metro stations and the last three to Line 2 metro stations. Various evaluations were performed using ArcGIS, which revealed the degree of effectiveness and efficiency of the street network, as it relates to a pedestrian- and transit-oriented mobility system. From these analyses a few definitive characteristics were clear. First, it is clear that the metropolitan area suffers from an extreme deficiency of arterial roads. Currently, approximately only 38% of the urban area is within walking distance of an arterial road. To intensify this problem, large blocks, with large impenetrable buildings are built along the few arterial roads that exists limiting access to and from residential neighborhoods. Furthermore, there is a severe lack of connectivity between neighborhoods. This has culminated in a situation where residents may have only one or two points of entry to or exit from their neighborhood. Consequently, residents within walking distance of a metro station are often forced to walk much further than a straight-line distance would provide. This is more prevalent in formally planned neighborhoods, than in informal settlements. Another important finding was that informally built neighborhoods are characterized by dead-ends due to geographic barriers such as rivers and rough terrain, where

as formally built neighborhoods generally control these barriers. On the other hand, formal neighborhoods. The result is that formal neighborhoods tend to have better internal street connectivity than informally built neighborhoods, while informal neighborhoods have better external street connectivity than formal neighborhoods.

Once the spatial analysis was completed, an on-site visit was conducted, which reinforced the severity of poor street connectivity in the metropolitan area. While only two of the five neighborhoods were visited, it is clear from the spatial analysis that similar issues likely exist throughout the metropolitan area. The on-site visit revealed that while the formal network's exhibits poor connectivity, locals have made make-shift connections that alleviate the effect disconnectivity has on their lives. Holes through fences, desire lines, and make-shift bridges were found throughout the neighborhood. While locals have made attempts to break down barriers to connectivity, many areas are just too difficult to penetrate without heavy construction. This is mostly due to rough terrain and wide sections of rivers. Another factor that was revealed by the on-site visit was that spaces where connectivity could be improved are quickly being filled in by informal builders. This makes the need for action even more urgent.

Recommendations were formulated based on the spatial analysis and the on-site visits and are grouped into two categories: corrective and preventative. The purpose of these policy recommendations are meant to direct the street network in a way so that it becomes supportive of a pedestrian- and transit-oriented mobility system. The six corrective policy recommendations are formulated to direct government officials, planners and community leaders on how to improve connectivity within their existing jurisdictions. These types of policies must be actively pursued, and ideally, through guidance of a planner with a critical eye and an understanding of the importance of connectivity. Furthermore, these types of policies require community participation. The eight preventative policies are intended to guide future development through standards, which are less open for interpretation as are corrective measures. The recommendations are presented in Chapter 5. The following sections elaborate on the rationale that led to these policy recommendations, and they are followed by the report's conclusions (Chapter 6).

Chapter 2: Context & Literature Review

2.1 Spatial Context

The area of study for this report is what will be referred to as the urban extent of the Panama City Metropolitan Region (AMP). It is the same urban area included in the *Plan de Acción* of the Panama Metropolitan area published in 2015 by the municipal government of Panama. Figure 2.1 below, shows the dimensions of the urban extent as spreading 80 km along the Pacific Ocean from Chorrera in the West and Paso Blanco on the Eastern edge. The urban extent then stretches north from the Pacific Ocean approximately 27 km along the Transistmica Highway that connects Panama to Colón. The estimated land area is 320 km² according to the *Plan de Acción* (2015).



Figure 2.1: Spatial dimensions of Panama City's urban extent.

2.2 Historical Morphological Analysis

2.2.1 Geographic and Environmental Constraints

Panama City was officially founded in 1519 as a Spanish colonial outpost, but the city's contemporary history began in 1903 when it achieved peaceful independence from Colombia. This paved the way for the US construction of the Panama Canal (Sigler, 2014). Until that time, the city hadn't exceeded 30,000 people. Today the metropolitan area holds about 1.9 million, meaning that the urban area grew by over 6,000% in just over 100 years. As the city grew it was forced towards the North and East due to Pacific Ocean on the South and the Panama Canal Zone on the West. This resulted in what Sigler (2014) describes as the city being constrained to a 30-degree wedge (Figure 2.2). Uribe (2007, p. 544) said this constraint in Panama City set in stone a pattern of growth that characterized its structure. Excluding the city's western suburbs, which grew rapidly after the handover of the Canal, the city's footprint resembles a 'Y' with a shortened stem (Porras, 2014).



Figure 2.2: Panama City has been constrained to a 30-degree wedge

Overall, Panama has been unable to grow concentrically, which has resulted in growth in locations that are far from the center, but also far from each other. Angel et al. (2011) compiled a database of the 3,646 most populated cities and metropolitan areas in the world and various variables which were meant to capture characteristics of the urban extent based on data from the year 2000. In terms of compactness, meaning the degree to which a city resembles a circle, Panama City ranked as the 400th least compact city out of 3,646 cities. Generally, compactness refers more to the density of a settlement; however, Angel et al. (2010) use the term to refer to the circle which is considered the most compact shape. However, in their calculations they did not include the urban areas west of the Canal. It can be assumed that if they had been included, Panama City's rank would have been much lower, reflecting an even less compact city.

2.2.2 Demand for land by firms and households

Panama's strategic location as the narrowest point between the Atlantic and Pacific Oceans has positioned it as an important player in global trade for centuries. This is the most essential piece to Panama's historical and contemporary economic growth (Sigler, 2014). This has meant that Panama's economy has historically been based on trade and services rather than agriculture or industrial manufacturing. At the same time, it resulted in a long-time urbanized society, unlike its regional neighbors whose societies and core economic activities were based mostly on rural haciendas (Sigler, 2014; World Bank, 2013).

By the 1980s Panama was a somewhat dense city. Its five wards had densities over 100 people per hectare, while El Chorrillo, a central and poor district, had a density of over 600 people per hectare. As these high densities can attest, the 1980s and 1990s were periods of severe undersupply of formal housing. During these two decades, informal housing was increasingly being built on public lands at the outskirts of the city (Sigler, 2014a). It wasn't until the handover of the Canal from the U.S. to Panama in 1999 that the demand was beginning to be met by the construction boom which really took off in 2003 according to Sigler (2014) and Porras (2014). Sigler (2014) stated that the "recent real estate boom in Panama City is the result of demand spurred by prevailing geo-economic conditions, underlain by a chronic undersupply of housing resulting from neoliberal-oriented state retrenchment." By "prevailing geo-economic conditions," Sigler is referring to increased global trade which resulted in more income from the Canal, now owned and operated by the Panamanians. Today, the metropolitan area has a density of 54 people per hectare, a similar density to that of Ulaanbaatar, Mongolia, Tokyo, Japan and Quito, Ecuador.

A growing economy translated into local demographic and economic shifts. Everyday Panamanians were seeing a greater purchasing power. In addition, Panama saw the emergence of property as a means of capital investment. At the same time, there was an urgent need to accommodate natural and migrant population increase (Sigler, 2014). Between 2000 and 2010 Panama welcomed a large amount of foreign capital, firms and individuals, especially from Colombia and Venezuela who found Panama a safe haven with a growing, stable economy tied to the US Dollar. Porras (2014) said the city entered “a frenzy of economic activity fed in large part by foreign investment.” Even though residential properties were mostly being consumed by Panamanians, the factors directing economic growth and investment were very much so linked to global forces (Sigler, 2014).

The demand for housing had been on the rise for years. Political instability in neighboring countries and natural growth within Panama increased housing demand. On top of this, the Panamanian economy was growing due to control of the canal and its importance in global trade, meaning housing demand was growing and diversifying for portions of the population. Therefore, demand had to be met one way or another. In Panama, housing demand was partially met through the private sector, in a way that Porras (2014) describes as “binge” development. However, as of 2010, 40.83% of housing was in the form of informal housing (Espino and Gordón, 2015).

2.2.3 Policy constraints that govern land use and spatial interactions in the city

“As transnational flows of capital triggered construction either directly through property investment or indirectly through demand derived from economic growth... The historical development of Panama as a commercial (rather than industrial or agrarian) economy, parallel to the sustained US occupation, ensured that its state has played a marginal and regressive role in property development, particularly in the recent past.” (Sigler, 2014)

As the quote above reveals, an important aspect of urban expansion in Panama is the marginal role government played in development. As mentioned above, Porras (2014) terms the type of development that occurred during the housing boom “binge” development. By this he describes a type of development which is “entirely present-focused, excessive and seemingly oblivious to future repercussions.” Porras (2014) makes a strong case that this became the case in Panama because the construction industry and real estate developers were deficiently regulated by traditional

government interventions such as forward-looking zoning regulations or public housing quotas. On top of this, the extension of credit to low-income families wishing to buy a home became increasingly widespread in the 1980s. While suburbanization had been occurring since the 1950s, it was the extension of credit in the 1980s that triggered large scale suburbanization similar to what occurred in North America (Jackson, 1987; Sigler, 2014). While this isn't entirely true for all of Panama's contemporary urban history, it is apparent in recent times, especially since the handover of the Canal in the late 1990s.

In the mid-20th century, as a result of disused agricultural land at the periphery of the city, the government was able to acquire large tracts of land for settlement. This resulted in "semi-formal land invasions" of migrants from the countryside. Entire districts such as Arraiján, San Miguelito and Pacora were settled and comprised makeshift or self-constructed housing. Through upgrading and titling schemes these homes were, for the most part, "formalized within the last few decades (Sigler, 2014)." In addition, the government actively pursued state-housing projects in the original urban slums such as El Chorrillo (Sigler, 2014). However, beginning in the 1980s, state retrenchment in housing meant that the government purchased far less land and quickly cut social housing projects (Sigler, 2014). A regressive state meant that private actors would be responsible for housing the growing and more economically diverse, yet polarized population.

The institutions which advocated for housing provisions for the poor (i.e. Bank of Urbanization and Rehabilitation (1944); Economic Development Institute (1953); Institute of Housing and Urban Development (1958)) were each dissolved and replaced in 1973 by the Ministry of Housing (MINI) and the National Mortgage Bank (Porrás, 2014). Both were placed with responsibilities of urban planning and public housing. The establishment of the National Mortgage Bank and the rise of private banking coincides with Panama's shift in the 1970s from a primarily renter population to a majority owner population (Sigler, 2014). Today, urban planning, land use and infrastructure responsibilities are still under MIVI, but are diffused further between Ministry of Public Works (MOP) and the Institute of Water and Sewerage (IDAAN). This complicates government functions which are already weak (Sigler, 2014).

In 1997 a metropolitan area plan was formulated to guide future growth and prepare for the reintegration of the Canal Zone into the hands of the Panamanians. The central recommendation of the plan was to decentralize the metropolitan area's employment and commercial activity in order to reduce congestion and infrastructure pressure on the central city (Sigler, 2014). However, as Porrás (2014) points out, the plan was never given legal effect and was ultimately ignored by every level of government. As mentioned earlier, since the 1970s, mortgage credit has been

increasingly more widespread and available in Panama. Full interest subsidies are available to those buying homes for under USD 35,000 (today \$40,000 according to Espino and Gordón (2015)). By 2007, these “preferential loans” made up around 62% of the metropolitan mortgage market (Sigler, 2014). Nonetheless, informal housing and social housing are a large part of the housing supply. For example, of homes constructed in the Metropolitan Area from 2006 to 2010, 2.35% was in the form of social housing and 38.97% was in the form of informal, or make-shift housing. In La Chorrera, informal housing made up nearly 59% of housing in this time period, while social housing accounted for only 0.15%. Almost the entirety of social housing in the metropolitan region has been constructed in Panama, San Miguelito and Arraiján.

As a result of state retrenchment in social housing and land provision, increased mortgage subsidies and access to credit to lower-income households, a loosely regulated construction and real estate industry, and a lack of legally-enforced planning regulations, policy constraints have been few. It would be accurate to say that the lack of policy constraints has shaped the AMP’s urban extent. This lack of constraints, a rapidly growing and wealthier (natural and migration) population and the Pacific and the Canal Zone have collectively produced a growing and elongated urban footprint that is increasingly centralized, fragmented, but less compact and dense than in the past.

2.3 Literature Review

The literature review is divided into three parts. The first section is a brief overview of the history and rationale of the modern street network. This historical review is not universal or culturally inclusive and does not claim to represent the evolution of street network design in its entirety. The idea is to trace the rationale behind Panama’s street network design. That being said, the current laws and regulation governing the construction of the street network in Panama have been heavily influenced by the same standards that regulated streets in the United States. Furthermore, Panama was originally colonized by the Spanish and traces of Spanish colonial planning can be found in older urban areas such as Casco Antiguo. Therefore, the history and theory behind street network design in Europe and the United States is relevant to the study of the current street network in Panama.

The second section of this literature review explores what a pedestrian- and transit-oriented street network looks like. Recently, there seems to be newfound interests among urban planners, traffic engineers, city leaders and the public on how the street network design affects our day-to-

day lives. Most of the recent discussion on the street network revolves less around a specific desired street type and more around the network's connectivity.

Finally, the third section of this literature review looks at the street network in the context of rapid urbanization. Panama is facing challenges that are not appropriately covered in the discussion of street network design taking place in the United States and Europe. Rapid urban growth is expected to continue in Panama as it has for the last few decades. This means that Panama must not only face the challenge of low connectivity of the existing network, but must actively plan for future growth at the periphery of the city. Once these areas have been explored, the information can be used to inform recommendations to government authorities, civic leaders and the public as a whole on what changes should and can be made to the street network so that the population of the AMP can rely less on the private automobile and more on public and active transportation.

2.3.1 History and Rationale of the Modern Street Network

The modern history of street network design has three main components: the gridiron, curvilinear street and street hierarchy, and standardization of both. The following section will elaborate these three components.

a. The Gridiron

The street grid or gridiron has varied in popularity in modern history, but it dates back to 450 B.C., when Hippodamus, a Greek town planner, developed a system of straight, parallel streets (Handy et al., 2003). Later it was adopted by the Romans who adapted it to their particular needs. For example, they established a gridded street hierarchy with mandatory widths and elevated sidewalks on wider roads. However, the fall of the Roman Empire in 476 A.D. signaled a decline of the gridiron. During the Middle Ages, cities built walls for protection, which was followed by overcrowding. Competition for space resulted in individuals taking over public space, including streets. Buildings took precedent over the right-of-ways for the movement of people and goods and narrow passageways became the norm. Due to lack of space and poor mobility, streets became filthy and dangerous (Southworth & Ben-Joseph, 2003; Handy et al., 2003).

In the 11th century, Europe entered a new era of increasing population and trade which gave rise to the removal of walls. The burgeoning merchant class, with its newfound power, was able to exert power and force authorities to improve street conditions and expand its network.

Straight lines that opened up dramatic perspectives of civic and religious buildings and the “pure form” of the grid appealed to the Renaissance architects. Similarly, military strategists admired the grid for its ability to mobilize forces in time of civil unrest or external attacks (Southworth & Ben-Joseph, 2003). As it was, in the first centuries of the new millennium, a new series of gridded streets began expanding from existing and jumbled urban cores in cities such as Berlin, Vienna and Turin (Handy et al., 2003; Southworth & Ben-Joseph, 2003). The grid was relatively consistent from this point forward appearing for the first time in the United States in the late 1600s when Philadelphia adopted the grid in 1682. Handy et al. (2003, p.3) say, “The grid so swayed American leaders of the late 1700s that conformance was mandated by the Northwest Ordinance of 1787 for all trans-Appalachian expansion. The result of that legislation is the ubiquitous influence of the gridiron on urban form from coast to coast.” Arguably the most famous example of the American grid was the 1811 Manhattan grid. Since its implementation, it has structure growth and city life for over 200 years (Ballon, 2012).

While most cities in the United States grew from the start with the grid, in Europe reordering of the existing streets and provisioning for future streets were simultaneous challenges. In 19th century Europe, the concept of unitary order was applied to the whole urban fabric, not just specific areas (de Sola-Morales, 2013). Common examples include Haussmann's Plan for Paris and Cerda's 1859 Ensanche plan for Barcelona. In 1844 in London, the First Report of the Commissioners of the State of Large Towns and Population Districts was published and called for widening and straightening of streets to be done in a concerted effort rather than in small patches. The commission of the report stated that “The widening and straightening of streets should be down in concert, rather than leaving improvement to an occasional widening project. The determining feature in each street would be an imaginary center line drawn on an official map from which all building lines could be controlled in the future. As old houses became ruinous they would be pulled down and new structures erected farther back” (as quoted in Southworth & Ben-Joseph, 2003).

However, by the early 1900s, the grid came under attack and slowly throughout the following century it was replaced with street network designs composed of curvilinear residential streets and cul-de-sacs and regulated by an adherence to street hierarchy classifications. Recently, an interest in the grid seems to be returning. As part of their checklist, Ewing and Bartholomew (2013) deem a grid-like street network as a highly desirable characteristic of pedestrian- and transit-oriented streets. Gridiron street networks are often synonymous with small blocks, but the two are conceptually distinct (Ewing & Bartholomew, 2013). That is because grids can exist with varying block sizes, and curvilinear street patterns can exist with small blocks. Therefore, they argue that while grids are advantageous, blocks size and intersection frequency are more essential. Ewing

& Bartholomew arrive at the conclusion that the optimal street network is that of a hybrid or grid-like street network. They argue the point presented by Tunnard and Pushkarev (1963), which is that “hybrid street networks can have an order to them that is easily perceived by travels, but an order that is not simple, mechanistic, and monotonous like that of a standard grid. It is a complex order (variety within unity) that affords the best possible aesthetics.” Below in Table 1, the advantages and disadvantages of the street grid that have been cited by Ewing & Bartholomew (2013), Handy et al., (2003) and others.

Table 2.1: Advantages and disadvantages of the gridiron

Advantages	Disadvantages
Simple and efficient (Handy et al., 2003)	Ignores topographical variables (Handy et al., 2003)
Economically beneficial method of subdividing land (Handy et al., 2003)	Monotonous (Handy et al., 2003)
Traffic is more evenly dispersed (Ewing & Bartholomew)*	Without restriction or variable road widths, it allows for evenly distributed traffic on commercial and residential streets (Handy et al., 2003) *
A rectilinear grid can reduce developer costs for road infrastructure* (Ewing & Bartholomew, 2013; Steuteville, 2009)	Requires too much space for streets (Ewing & Bartholomew, 2013)
maximized the number of houses facing a street (Handy et al., 2003)	Maximizes pedestrian and vehicle interaction (Handy et al., 2003)
minimized legal boundary dispute (Handy et al., 2003)	Safety. Ewing & Bartholomew (2013) state that “Shorter stretches ending in T-intersections are particularly effective in reducing speed, crash frequency, and crash severity.”
allowed for standardization of lots (Handy et al., 2003)	
provides psychological comfort to a growing nation (Jackson 1985, 75)	
simplified surveying (Handy et al., 2003)	
Offers pedestrians direct routes and the option to travel along high-volume routes or not	
Allows transit vehicles to avoid backtracking and frequent turns	A * appears when the factor is seen as both an advantage and disadvantage

b. Curvilinear Street Design and Street Hierarchy

The rationale for abandoning the grid street structure was originally formed based on two unique contexts: The English experience and The American experience. In 1875, the Bye-Law Street Ordinance was adopted in England to adjust many of the urban ills plaguing the city at the time (Handy et al, 2003; Southworth & Ben-Joseph, 2003). The ordinance increased street width and improved sanitation, but resulted in what residents considered a monotonous and sterile landscape. This was applied to residential neighborhoods and rendered the intimacy of neighborhoods to stone walls. In response, two successful neighborhoods (Bedford Park, and Hampstead Garden which was designed by Raymond Unwin and Barry Parker in 1904) were designed and permitted to be built that ignored the regularity of the street grid and opted for curvilinear streets, cul-de-sacs and narrow residential streets that had a high degree of connectivity to wider roads on the periphery. These neighborhoods also ensured pedestrian connectivity by connecting cul-de-sacs to other streets mid-way or at the end to other streets with pedestrian paths (Handy et al., 2003). This was the foundation of curvilinear street design and street hierarchy. This fundamentally changed the relationship between streets and buildings (Marshall, 2005).

In the United States, Frederick Law Olmsted and Calvert Vaux attempted to reproduce and implement curvilinear street patterns. However, it wasn't until the rapid increase in vehicle ownership in the 1910s and 1920s that there was enough momentum for the mainstream to turn their backs on the rectilinear grid. Since the grid made every street equally inviting for through traffic, once quiet residential streets were suddenly crowded with parked cars and through traffic (Handy et al., 2003). In 1900 only 8,000 cars were in American cities and towns, but by 1920 there were an estimated 8 million and by 1930 that number grew to approximately 23 million (Handy et al, 2003; Southworth & Ben-Joseph, 2003). The influx of vehicles made a city built for pedestrians and horse-drawn wagons feel suffocated and clogged. When the time came, Unwin and Parker's method was already available and had proven successful in England.

As mentioned above, The Romans introduced the concept of street hierarchy within a gridiron street network. They created a hierarchy of streets based on widths and function. It was mandated that the principal east-west thoroughfare, or *decumanus*, be 12 m wide to accommodate ceremonial processions and heavier through traffic, the main north-south route, or *cardo*, be 6 m wide and the side or local roads being at least 4.5 m. The wide processional roads were also the roads that connect cities to each other on the Roman *viae militares*. Due to increased trade and travel throughout the Roman Empire, it was reasonable that travelers and traders, as well as military fleets, could pass through a city without crowding

local streets and disrupting daily life. The Romans faced the same challenges that led to the adoption of street hierarchy in recent times. They felt the need to calm through traffic as it created congestion and a dangerous environment for pedestrians and residents on local streets while facilitating the continual flow of traded goods. They even placed stone blocks at certain street entrances to discourage through traffic (Homburger et al, 1989). In Donald Appleyard's *Livable Cities* (1981), he describes neighborhoods in San Francisco and Berkeley which used diagonal diverters and chokers to reduce through traffic on residential streets in neighborhoods within the grid network.

As a response to the increase in automobiles on residential streets, the rationale for a system of hierarchical streets was reached. In the same way that the Romans developed the decumanus and cardo, the American street hierarchy was originally meant to accommodate vehicular movement and to mitigate the negative impacts of congestion on residential streets. In 1928, Clarence Perry and Clarence Stein developed a revolutionary plan for Radburn, New Jersey, which not only applied curvilinear streets, but established a street hierarchy. Narrow residential streets and cul-de-sacs were superimposed on 35-50 acre superblocks surrounded by wide collector streets, similar to Hampstead Gardens. There were extensive pedestrian paths that separated the flows of vehicular traffic from foot traffic. Likewise, residential and commercial uses were entirely segregated, which at the time was seen as impractical (Handy et al., 2003). The rigid separation of uses differentiated Radburn from the English models of Hampstead Gardens and Bedford Park.

The *Subdivision and Site Plan Handbook* (1995) stated that the street hierarchy system is “defined by road function as measured by average daily traffic” (Listokin & Walker, 1989, p.296). Streets hierarchy typically categorizes streets into four principal categories: residential access streets, residential sub collectors, residential collectors, and arterials. This hierarchy suggested that all housing should be on residential access streets, however, if unavoidable then housing could be placed on residential sub collectors which are not to connect to any adjoining neighborhoods or subdivisions as to discourage any shortcutting by through traffic. Streets in a traditional grid functioned as access points and movements routes, but in a street hierarchy model, a street’s classification determines where it is placed along a spectrum of land access and vehicular movement (Handy et al., 2003; Marshall, 2005). Whereas a cul-de-sac has the sole purpose of land access, a freeway has the sole purpose of vehicular movement, with other streets somewhere in-between the two (Handy et al., 2003). This model has been widely implemented due to standardization over the last few decades.

In both the American and English examples, the rectilinear street grid seemed to have taken the blame for urban problems that had a whole slew of contributing variables. In England, it wasn't the straight streets by themselves that made the environment monotonous and sterile. Streets were too wide and the architecture was monotonous and lifeless. In the United States, it wasn't the grid by itself that created the problem, but the fact that cities didn't plan for the onslaught of the automobile. While the idea of street hierarchy was not new, it was the first time that it had been planned for in conjunction with curvilinear street design and cul-de-sacs. This strand of planning is what Spiro Kostof (1991) calls “planned organicism” or “planned picturesque.” Before this era of planning, distinctions between planned and unplanned streets were more easily made.

c. Standardization

The success of Radburn influenced the modern residential suburban development. Once standardized, rapid reproduction of curvilinear streets embedded within a hierarchical street network began (Handy et al, 2003). The standardization of the modern suburb commenced with the creation of the Federal Housing Administration (FHA) in 1934. From its beginning the FHA began exerting considerable control over the direction of the housing market, and in 1935 it published a booklet of standards for subdivisions. It specified that blocks should range from 660 to 1,000 feet in length that density for semidetached housing should not exceed 12 units per acre and that subdivisions should fit the topography (Southworth and Ben-Joseph, 1997, 2003; Handy et al., 2003). Then in 1936 the FHA published *Planning Neighborhoods for Small Houses*, which based much off the recommendations of Unwin, Perry and Stein's work. For example, it recommended that the inclusion of cul-de-sacs makes the most attractive street layout (Southworth and Ben-Joseph, 1997, 84). By 1941, municipalities had full control of setting subdivision standards; however, the standards recommended by the FHA were widely adopted and enforced throughout the U.S (Handy et al., 2003).

In 1961, a decisive study was published that compared the accident rates between gridiron streets and those of FHA guided neighborhoods. It demonstrated that the FHA model decreased accident rates dramatically. However, the study has since been shown to be seriously flawed. As Handy et al. (2003) point out, it did not control for difference in traffic volume, land use, density, lighting or any other factors that might be responsible for vehicle accidents (Southworth & Ben-Joseph, 2003, 100; Handy et al., 2003). Today, it is commonly argued that a higher frequency of intersections and more narrow roads are safer for pedestrians (Ewing, R. & Bartholomew, K. 2013). Nonetheless, in 1965 the Institute of Transportation Engineers published *Recommended Practice for Subdivision Streets* in 1965 which further encouraged the design of hierarchical streets while prescribing a set of standards that aimed at efficient vehicular movement (Southworth & Ben-Joseph, 2003). It prescribed standards

such as minimum widths on residential street right-of-ways of 18.3 m with a minimum pavement width of 9.8 – 10.4 m and cul-de-sac max lengths at 305m with a 15.25m radius circle at the end. They published two more editions, one in 1984 and the other in 1990 that perpetuated the concept of street hierarchy (Handy et al, 2003). Despite a few minor adjustments, the 1984 and 1990 reports were left practically unchanged (Southworth & Ben-Joseph, 2003).

By the 1980s the concept of street hierarchy and curvilinear streets as the preferable means to mitigate traffic on local residential streets and create a desirable residential neighborhood was in full-force. This is demonstrated by *The Subdivision and Site Plan Handbook* (1995) which incorporated a number of improvements to subdivision controls that the authors believed were critical, street hierarchy being a principal improvement. For example, they argued that street width standards should be narrowed to avoid costly overbuilding. As part of the recommended improvement of standards, the authors claimed streets to be a key area where subdivision and site plan ordinances required unnecessary improvements and costly overbuilding. As reflective of the time, they entirely embraced street hierarchy and curvilinear streets as a means to achieve safer, convenient and quieter neighborhoods. Streets were meant to reflect their function (Listokin & Walker, 1989).

While the original rejection of the grid was meant to mitigate traffic on residential streets and improve the quality of life of residential neighborhoods, many decades later, it has resulted in an extreme decline in street connectivity and in many ways has become a hostile environment for pedestrians. The original intention of street hierarchy proposed in the Radburn plan looks very different from the conventional and standardized suburban design found in many cities in the U.S. and globally. Southworth and Ben-Joseph (2003) explain that problems arise “when standards intended for health and safety overstep their bounds and lose grounding in objective measures of goodness or a connection with the original rationale for their existence.” Likewise, In *the Subdivision and Site Plan Handbook* (1995), the authors state that “constant reevaluation is imperative to foster economical and well-designed development...” That being said, there has a growing concern with the negative side effects caused by the proliferation of standardized street hierarchy in city planning, namely the lack of street connectivity. This is reflected in the fact that many cities in the United States and globally are adopting pedestrian- and transit-oriented street design ordinances and guidelines (Handy et al., 2003).

Like cities in the United States, Ciudad de Panamá has adopted a land development plan that layouts a network of hierarchical streets. In Articles 22 – 24 of *El Reglamento Nacional de Urbanizaciones, de Aplicación en el Territorio de la República de Panamá*, outline the function

and form for six types of streets (arterial roads, collector roads, local roads, marginal roads, dead-end streets, and pedestrian paths). The oldest neighborhoods in Panamá, such as Casco Antiguo, La Exposición and Colón, were arranged and built within a gridded framework, where all streets function with equal capacities. However, the streets of formally built neighborhoods, since, have been built according to the street hierarchy requirements. It is important to note that the prevalence of curvilinear streets does not seem to be a prominent feature of subdivision design in Panama with only a few exceptions. If street hierarchy standards are to remain then their rationale must be understood and reapplied or abandoned. It is difficult to know if municipal leaders at the time adopted street hierarchy standards in full comprehension of their rationale or not. If so, are they still grounded in “objective measures of goodness” or do they retain a strong “connection with its original rationale?” The following section explores what the current literature has to say about the characteristics of and ways to achieve a pedestrian- and transit-oriented street network.

2.3.2 Alternative Street Network Design

At the turn of the century, there appears to be a trend moving away from standard subdivision street network design. While new developments in the U.S. and elsewhere are still entrenched in a framework of standards, a few other approaches such as Traditional Neighborhood Design (TND) supported by New Urbanism, Pedestrian-Oriented Development (POD), and Transit-Oriented Development (TOD) are offering alternatives to conventional subdivision streets and street network design (Southworth & Ben-Joseph, 2003). A major component of each of these is a high level of pedestrian connectivity that encourages walking. TNDs are more prescriptive on building design, while PODs and TODs place less emphasis on architectural form and more on transportation and movement in general (Southworth & Ben-Joseph, 2003). This section of the literature review will look at what these alternative neighborhood design strategies say, collectively, about a street network design that strives to encourage walking and the use of public transit.

Overall, the common theme found throughout the literature is the importance of connectivity. In particular, in the United States local municipalities have been revamping and in some cases completely overhauling regulations that govern the construction of the street network to ensure greater degrees of street connectivity (Handy et al. 2003). Not only are municipalities seeing the added benefits of a more connected network, but demand for more walkable environments and access to public transit is also growing in the United States (Ewing & Bartholomew, 2013).

a. Street Connectivity

Highly connected street networks were the norm in city planning became fixated on the automobile (Handy et al., 2013; Rappaport, 1990; Machemehl, 2012). Street connectivity can be defined as a system of streets in which multiple routes and connections serve the same origins and destinations (Kentucky Division of Planning, 2009; Victoria Transport Policy Institute; Handy et al., 2003). While this is accurate, it should be added, or at least clarified, that a highly connected street network is one in which multiple routes and connections serve the same origins and destinations without the need of arterial streets. This manifests as a street network with many short links, numerous intersections, and few cul-de-sacs or dead-ends.

In *Pedestrian- and Transit-Oriented Design*, Ewing and Bartholomew (2013) tie together urban design literature and empirical research on travel behavior, visual preference, real estate economics and traffic safety to compile a 28-point checklist for an ideal pedestrian- and transit-oriented area or neighborhood. The authors arrange these 28 points into three groups: essential, highly desirable, and worthwhile but less essential. Of those deemed essential, short- to medium-length block was identified and deals directly with street network design. While other characteristics are extremely important to desirable pedestrian and transit oriented areas, this report focuses on the fundamental characteristic of the layout of city streets.

In terms of promoting walkability, the authors point to a few reasons why smaller blocks are key. Most obviously, they say, small blocks force cars to stop and allow pedestrians to cross the street more often. Secondly, they acknowledge the fact that a dense network of streets disperse traffic more evenly allowing for streets, altogether, to be scaled down to pedestrian-friendly levels. An interesting aspect that Ewing and Bartholomew (2013) discuss, but which is less commonly acknowledged are the optical and psychological factors that small blocks have on the pedestrian. For one, small blocks increase the percentage of time pedestrians spend within fine-detail focal distance of the next intersection. This is due to the fact that humans can perceive fine-detail within 45.7 meters. They claim that frequent intersections also give pedestrians more control and freedom since different routes from point A to B are possible. Finally, they state that more frequent intersections and small blocks shorten the sense of time on walking trips since “progress is judged to some extent against the milestone of reaching the next intersection.”

In the last couple of decades, there has been an increased awareness of the importance of street connectivity as well as action taken to achieve it (UN-Habitat, 2013; Handy et al., 2003). In 2013, the UN-Habitat added street connectivity as a factor in their *Prosperous City Index*. Table 2 below, presents a list of real and/or perceived advantages and disadvantages of street connectivity.

Table 2.2: Advantages and Disadvantages of street connectivity

Advantages	Disadvantages (Handy et al., 2013)
Decreased traffic on arterial streets (Kentucky Division of Planning, 2009; Handy et al., 2003)	Increased levels of through traffic on residential streets
Increase of continuous and direct routes that encourage non-motorized means of travel (i.e. walking, biking), which in turn results in a more efficient public transit system (Handy et al, 2003; Kentucky Division of Planning, 2009)	Increased infrastructure costs and impervious cover require more land to develop same number of unit
Provides greater emergency vehicle access and reduced response time, as well as multiple routes of evacuation (Handy et al, 2003)	Decrease the affordability of housing
Improves the quality of utility connections, facilitate maintenance, and enables more efficient trash and recycling collection and other transport based community services (Handy et al., 2003)	Threatens the profitability of developments
Increased neighborhood physical and visual permeability (Bentley et al., 1985; Ewing & Bartholomew, 2013)	
Lowers levels of air pollutants “land use patterns that favor smaller parcels of land, and increased intersection density are positively associated with the decrease in vehicular travel and emissions” (UN-Habitat, 2013)	
Health benefits derived from increased walking (UN-Habitat, 2013)	

Street connectivity is measured by using various ratios, density measures and indices concerning block size and/or the distance between intersections. While smaller blocks and more frequent intersections are indicative of a more highly-connected, permeable network, there is no one-size-fits-all for cities. A context-sensitive approach should guide what a city determines as the optimal street connectivity (Handy et al., 2003). The next section will look into the tools that cities are using to increase the degree of street connectivity.

b. Tools to Achieve Greater Street Connectivity

In the last couple of decades, jurisdictions in the U.S. have acted to address poor street connectivity through land development ordinances. A large portion of implementations have centered on the ideas promoted by Smart Growth America's "complete street" concept, with over 300 jurisdictions adopting complete street policies. Street connectivity is an integral, although less glamorous, component of complete street policies. A foundational component of complete streets is that they exhibit high connectivity (Smart Growth America, 2010)

Two approaches have been most commonly used to address street connectivity: block length maximums and connectivity indexes, which quantify how well street networks are connected internally and/or externally (Handy et al., 2013). Panama has set a block length maximum; however, it is rather inward looking, meaning a single development's plans are only required to be present-focused, paying no mind to existing or future developments in its periphery. Furthermore, the block length limit is excessive. In Panama, blocks cannot exceed 350 meters and any block that exceeds 180 meters must provision a pedestrian path at the half-way point. No regulations apply to non-residential developments (R. de Panama, 1998). From a review of ordinances in the U.S., in general, maximum block lengths do not exceed 180 – 200m (Handy et al. 2003; Machemehl, 2012). In addition, cul-de-sacs have maximum limits in the range of 60m to 200m; however, many cities require pedestrian connections when cul-de-sacs are longer than a certain length. Overall, cul-de-sacs are generally discouraged. Furthermore, many cities have banned the construction of gated communities or gated streets. Of the twelve cities in which street connectivity ordinances were reviewed by Handy et al. (2003), ten cities strictly forbid gated communities, while the other two cities limit or discourage them.

The second, less-common approach to ensuring or increasing street connectivity is by requiring new developments to adhere to street connectivity indices. For example, a widely used connectivity index which has been implemented by Cary, NC, San Antonio, TX, and Orlando, FL is the link-to-node index (Handy et al., 2013). This index considers links as any street segment between two nodes. Nodes represent intersections,

cul-de-sacs and dead-end streets. The index is the ratio of a neighborhood or city's links divided by its nodes. Higher ratios indicate higher levels of connectivity (i.e. fewer cul-de-sacs and dead-ends).

The methods for calculating the index varies between cities. Some cities may count connections to arterial roads as nodes, while others would label a sharp edge as a node. Similarly, the desired ratio is set according to what is in the realistic realm and context of the city. For example, Charlotte, NC requires a link-to-node ratio of 1.45 for more urban, denser parts of the city and a ratio of 1.35 in areas that are more suburban in physical form (Machemehl, 2012). From a review of the current practices in the United States, a connectivity index of 1.40 or higher is seen a well-connected street network. Ewing & Bartholomew (2013) note that hybrid grid-networks generally have a link-to-node ratio ranging somewhere between 1.4 and 1.6, while grid network score much higher and conventional suburbs score much lower. A critique of link-to-node ratio is that it is not entirely intuitive (Handy et al., 2003). A more intuitive, useful when identifying the prevalence of cul-de-sacs

It is not advised to depend on any street connectivity index alone to guarantee high levels of connectivity (Handy et al., 2013). The advantage of using the link-to-node index is that it allows developers more flexibility when facing with constraining topography, while at the same time discouraging the construction of cul-de-sacs (Handy et al., 2013). Another important index used to measure the favorableness of a street network towards pedestrians is the pedestrian route directness ratio (PRD ratio). This ratio is useful when planning for pedestrians because it determines the efficiency of a street network based on how directly routes are oriented towards a certain destination. It is calculated by dividing the actual route a pedestrian must take to get from point A to point B divided by the straight-line or Euclidean distance from point A to point B. Planner can identify a specific origin-destination pair or they can calculate the average of all origin-destination pairs for an entire area. However, in order to make comparisons between locales, a certain distance from a specific destination, such as a metro station or school, must be decided upon. Otherwise, comparing averages is arbitrary since distance affects the ratio. A ratio of 1:1 is indicative of a street network that permits pedestrians to walk directly to a destination. According to UN-Habitat (2013) a PRD ratio of 1.5 is considered acceptable for a walkable environment.

Other connectivity indexes are walking permeability index, alpha index and gamma index (UN-Habitat, 2013). Indexes like walking permeability index combine numerous factors with specific weights (UN-Habitat, 2013). Also, the walking permeability index, alpha index and gamma index are far from intuitive and require more technical know-how. Therefore, in terms of their usefulness for policy implementation on a municipal level, they are too cumbersome. In addition to these connectivity indices, measurements such as street density, intersection density and

the proportion of land allocated to streets are commonly used to measure street connectivity, but are often critiqued for over-simplifying the situation.

Despite poor connectivity within subdivisions, a prevalent issue that is often mentioned in the literature is external connection. In the last few decades, countless subdivisions have been built with minimum connectivity to arterial roads. For example, in 1995, characteristics and standards of a functional street hierarchy were listed by *Urban Land Use Planning*. It grouped streets into five categories (Freeway/expressway, primary arterial, secondary arterial, collector and local). With each category, a recommended standard minimum intersection spacing was identified. In terms of continuity, it stated that collector roads and local roads should not exhibit continuity extending across an arterial road. In terms of intersection spacing, it suggests that primary arterial roads shall not have intersection closer than every $\frac{1}{2}$ mile (800 m), secondary arterials should not have intersections spaced any closer than $\frac{1}{4}$ mile (400 m). This sort of spacing is the result of a street hierarchy system based on vehicle function.

To combat this type of development the Regional Government for the Portland Area implemented a design option that required street connections along arterials to be spaced no further than 161 m apart (Handy et al., 2003). This corresponds to what researchers concluded from studies in the Portland Metropolitan area. They found that an optimal range of connectivity along arterial streets was somewhere between 10 – 16 connections per 1.6 km (Kloster et al, 2000). The city of Fort Collins, CO implemented 'traffic sheds' to ensure interior roads exhibit high connectivity with arterial roads. These 'traffic sheds' require a new development to distribute or 'shed' traffic to three different arterial roads in three different directions (Handy et al, 2013). Finally, simplifying ordinances and their language, as well as communicating the importance of street connectivity to citizens, are vital to ease the transition from a poorly-connected to a well-connected city. Machemehl et al. (2012) suggest that street stubs be marked with signs indicating that future connections will be made, and that codes and ordinances should be accessible in layman language and presented with visual aids to better communicate ideas to the community.

2.3.3 Street Network Design in the Context of Rapid Urban Development

Although population projections can be questionable, it is clear that the world has and will become increasingly more urban. Interestingly, the physical urban environment has been expanding at a greater rate than the population growth rate. Meaning settlements are becoming more sprawling over time. This is occurring in cities around the world, regardless of region, size or income echelon. This phenomenon has been recorded

by Angel et al. (2011) for the years 1990 to 2000. During this decade, urban population grew at a rate of 1.60% per year while the urban land coverage or urban extent grew by 3.66% per year, a 2.6% difference. The only option to reverse this trend is to increase density substantially. A strategy of containment has been implemented in many developed cities such as Seoul, South Korea, London, United Kingdom, and Portland, United States. Portland adopted an urban containment policy to contain urban sprawl. However, density has continued to decline in the urban extent. Between 1990 and 2000, its built-up area density declined by 6% per year. The Municipal Government of Panama has projected urban extent to grow by 1.60% per year from 2014 to 2050, while urban population is expected to grow by 1.66% per year. This would increase the urban density from its current 54.39 people per hectare to 55 people per hectare. In other words, they are projecting density to increase by less than 1% in 36 years (Plan de Accion, 2015). However, global trends would point to density going in the opposite direction, especially if Panama increases its wealth.

Much of the recent literature on street network design in the United States has primarily focused on street network design of subdivisions and site planning. While there is ample discussion of the necessity of connections to arterial roads, the discussion of the prevalence and spacing of arterial roads is less evident. It is possible that arterial roads are in abundance in the U.S. context and problems arising from a deficiency are not common. However, in developing countries where urbanization is rampant, growth is often so chaotic that little land is actually devoted to roads and, where road right-of-ways are provided, they are often too small to be considered arterial roads. Small, irregular roads prove constraining when providing public transportation and trunk infrastructure (Lamson-Hall et al., 2015).

Arterial roads play an important role in the movement of traffic and are also best suited to carrying trunk infrastructure and public transit routes. For the most part, they act as the highest order multi-functional streets in a city's street network hierarchy. The Subdivision and Site Plan Handbook (Listokin & Walker, 1989, p.299) states that the "function of arterials is to convey traffic between municipalities and other activity centers and to provide connections with major state and interstate roadways." The current subdivision ordinance in Panama relates arterial roads as streets with the primary function to communicate other sectors of the city with the subdivision. According to the laws that regulate the construction of subdivisions, the city's Official Street Plan has marked 20 meter right-of-ways for arterial roads. When an anticipated subdivision intersects or is affected by a right-of-way, the developer will have to build accordingly. Interestingly, however, the Official Street Plan does not exist and was never actually created. Therefore, developers do not have to address this issue and continue to build subdivisions without forethought towards the appropriate locations for arterial street right-of-ways. All the while, the local and federal governments are spending large sums on expanding the

expressway network, which is somewhat guiding where future care-oriented development takes place. The provision of arterial roads has been neglected by both the state and the private sector.

Angel (2012) argues that the market cannot be relied upon to provide arterial streets in appropriate corridors. He says “The network of arterial roads is a classic [common] good (i.e. users cannot be effectively excluded from using it). Since it is a [common] good, there is no market mechanism that can ensure that arterial roads are in adequate supply in appropriate locations. In other words, a shortage of arterial roads may be a form of market failure.” Angel et al. (2016), as part of the Atlas of Urban Expansion’s research, calculated walking distance to arterial roads and the density of arterials roads for a sample of 200 cities. Their findings suggest that the share of urban areas within walking distance of an arterial roads and the density of arterial roads has been decreasing globally, in both developed and developing countries. According to their report, on average, 92% of and built-up urban areas were within walking distance of arterial roads in 1990. In new urban areas from 2000-2013, this number had dropped to 82%. Likewise, the density of arterial roads (km/km²) has decreased worldwide from 2.01 km/km² in 1990 to 1.32 km/km² in new urban areas built between 2000 and 2013.

While the gridiron has more or less been abandoned in the United States, at least at the residential street level, many municipalities have for some time relied on an arterial street grid to guide expanding urban growth, while leaving the construction of local streets to developers. In 2015, Houston completely overhauled its outdated local bus system. The bus routes had largely remained the same since the 1970s. At that time, the city was relatively centralized with the downtown employment center surrounded by dense neighborhoods. Fast forward to the 2010s and Houston has become a polycentric metropolitan region with dense concentrations of people spread throughout the city. Fortunately, Houston has continually expanded its arterial grid at 1-mile intervals, meaning that nearly everyone is within ½ mile of an arterial street. Transportation planners were able to take advantage of this arterial grid and redesign the bus system into an orthogonal layout with fewer stops, but higher frequencies along the arterial roads. This resulted in a large increase in the population that would be serviced by high-frequency bus routes within a half mile of their home.

The majority of Barcelona exists on the grid laid out by Cerda’s Ensanche Plan of 1858. The blocks are evenly spaced at every 100 m, creating a tightly-knit grid. Recently, the city has embarked on a new urban structure of mobility called Superblocks. These Superblocks are being introduced with the aim of responding to the city’s scarcity of green spaces, and its high levels of pollution, environmental noise, accident rates,

and sedentarism (Ajuntament de Barcelona, 2017). The aim is to combine nine existing 100m-by-100m blocks into Superblocks or new urban cells with both interior and exterior components. The exterior component will act as the arterial roads hosting the orthogonal public transit routes and heavier traffic, while the interior component is closed to all through traffic (BCN ecologia, 2017), giving pedestrians more space free from traffic. Barcelona is essentially transforming its street network from a one-tier grid to a two-tiered grid network of local and arterial streets.

The dimensions of Houston's arterial grid and Barcelona's Superblocks vary significantly; however, both operate on a city-wide scale and have provided the opportunity to expand and universalize public transit and public, open space. Their evenly spaced grids have afforded these cities the flexibility to adjust their mobility systems to meet changing demands and needs of their citizenry. This alone points to the fact that planning for urban expansion in the most minimal way can be beneficial in the long run. Shlomo Angel (2012) has acknowledged this and has developed an approach called "Making Room for Urban Expansion." This approach is simple and can be applied universally. He recommends that arterial streets, those carrying heavier traffic and public transit routes, be spaced one kilometer apart in order to avoid intensifying congestion on arterial roads as well as guaranteeing universal access to public transit within a ten-minute walk. He also suggests that arterial roads should be anywhere from 20-30 meters wide so that they can accommodate designated bus lanes, bike lanes, a median and several traffic lanes. Lamson-Hall (2015) argues that "Arranging roads in a rectilinear grid creates a skeleton for the city that will maximize connectivity, encourage walkable growth, and minimize locational advantage, creating a more integrated metropolitan labor market and increasing productivity." While most developing cities have no such plan to speak of, a few cities have begun the process of actively planning for urban expansion.

Angel (2012) provides an example of the municipality of Milagro, Ecuador, which has developed a minimalist urban expansion plan, as well as the legal tools to achieve said plan. For example, under municipal law, the city can now obtain, at no cost, up to 10% of any land parcel that is being developed for use as a right-of-way for public works (Angel, 2012). Similarly, in 2013, Ethiopia's Ministry of Urban Development and Construction teamed with NYU to implement the Ethiopia Urban Expansion Initiative (UXI) which is intended to help rapidly growing cities in Ethiopia plan for their spatial growth through 2040 by means of provisioning and acquiring land for public right-of-ways and building roads and infrastructure. Four cities (Hawassa, Adama, Mekele, and Bahir Dar) have arranged and legalized plans for over 1700 km of 30m wide arterial roads and 81,000 hectares of land for expansion (Lamson-Hall, 2015). A simple look at satellite images on Google Earth show the plans are already underway.

2.3.4 Summary

Rapid urban population growth, failed urban planning, state retrenchment in housing and the unconstrained real estate and construction industries have collectively resulted in a regional street network that lacks adequate infrastructure and mobility for pedestrians. This in turn has resulted in a street network that is not suitable for a transit-oriented mobility system since transit is largely dependent on pedestrian access. Moving forward, Panama is faced with two questions. First, how should and could the current street network be modified to accommodate pedestrians and transit use? Secondly, how can the street network be planned or governed in a way that ensures a pedestrian- and transit-oriented network for the future? The history of Panamanian-style urban growth, the rationale for various street network designs and how rapidly growing cities can plan for future growth, has provided this report with the necessary information to proceed with an analysis of how Panama's street network functions in practice and to offer recommendations for the existing and future state of the street network in order to ensure a pedestrian- and transit-oriented system going forward.

The implementation and popularity of the grid has gone back and forth over the centuries, in a somewhat cyclical fashion. The encroachment of the automobile on cities fostered a fundamental shift in how streets interact with buildings and led to shift in preference from the grid to curvilinear streets and street hierarchy. However, over time, the increasing standardization of street hierarchy and curvilinear patterns has resulted in neighborhoods that are disconnected and offer a hostile pedestrian environment. Recently, alternative subdivision and site planning approaches all call for greater street connectivity to encourage walking and use of public transportation. However, a perfect gridded residential street network does not account for topography and is often perceived as monotonous. Thus, it seems unlikely that there will be a resurgence of a perfectly gridded network. A preferred method among new alternative approaches appears to embrace grid-like street networks that allow for variety within order.

Globally, but especially in developing countries, lack of planning has resulted in a deficiency of arterial roads which have proven vital for carrying heavier traffic, public transit routes and trunk infrastructure. Angel (2012) proposes that cities, at least, partake in a minimalist planning approach for what appears to be inevitable urban expansion. This would manifest as a network of adequately spaced arterial roads and could prove beneficial to cities experiencing rapid urban growth. Urban containment policies might not be preferable or appropriate for these types of cities. The next section will elaborate on the methodology implemented in this report. Following that section, the analysis and results as well as the

recommendations going forward will be presented. Finally, this report will conclude with the limits to the research as well as recommended research going forward.

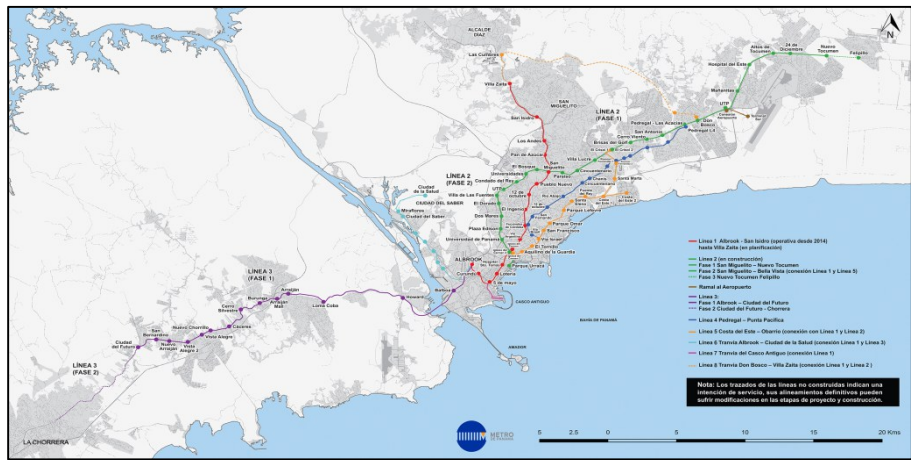
Chapter 3: Data & Methodology

Large sums of investment are being made on public transit in Panama City, specifically the metro rail system. Construction of Line 2 (Figure 3.1) is underway and construction on Line 3 (Figure 3.2) is set to begin in the near future. In a pedestrian- and transit-oriented city, the street network should play a supportive role for the public transportation network. This report does not attempt to address all important factors of transportation, land-use or urban design. Nonetheless, this report identifies ways in which the street network can guide Panama towards a pedestrian- and transit- oriented mobility system.

Figure 3.1: Current state Line 2 construction near Nuevo Tocumen Station



Figure 3.2: Master plan for the completed fixed-rail metro Network



Source: Metro De Panama. Government of the Republic of Panama

The study is not concerned with social, demographic or economic characteristics of the population; therefore, little external data was needed. In fact, the only external data used in the analyses were the street network shapefiles derived from National Institute of Statistics and Census of the General Controller of the Republic of Panama (INEC). Using the street network shapefiles, various analyses were performed to understand the degree of connectivity within the neighborhoods and throughout the metropolitan region. As was presented in section 2.3.2 of the Literature Review, many measures of connectivity exist, but only a few of them were implemented in this report. Firstly, some of the measurements were impossible to calculate given the available data. For example, the portion of land allocated to streets was impossible to calculate since city-wide data on existing street dimensions is not available. Secondly, indexes such as the walking permeability index, alpha index and gamma index are not intuitive were left out since they are not intuitive or easy to interpret. Listed below are the evaluations that will be presented in the next chapter:

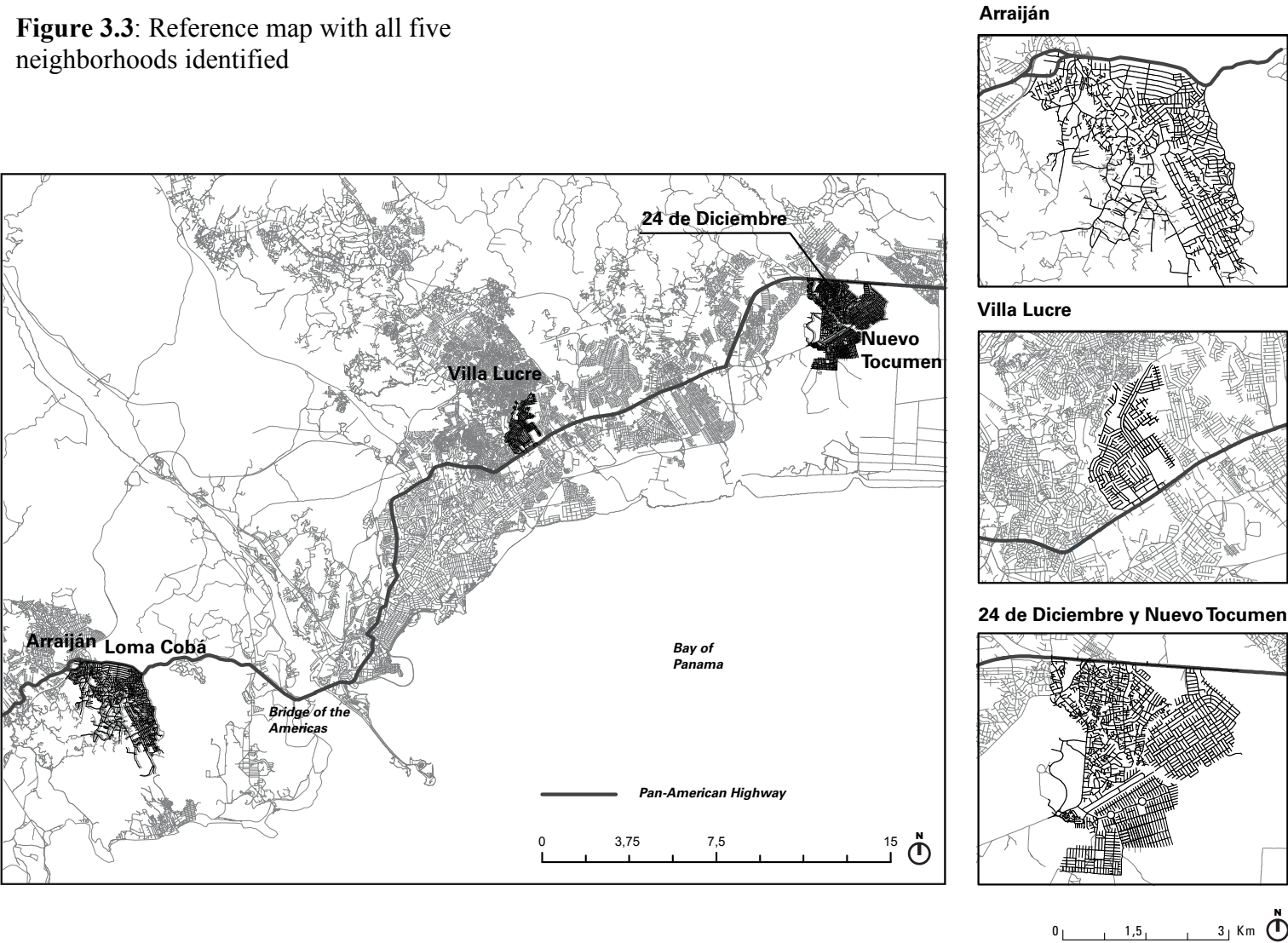
- Evaluation of arterial roads
- Evaluation of block size
- Evaluation of pedestrian route directness
- Evaluation of internal street connectivity (Link-to-Node Ratio)

From the results of the street network analyses, a series of issues were raised and a number of problem areas were identified. However, an analysis of the street network only tells part of the story. Therefore, an on-site study was necessary before making recommendations. Due to time limitations, the on-site study was narrowed to Nuevo Tocumen and 24 de Diciembre. To document the site visit a series of photos were taken of various factors that relate to pedestrian infrastructure and street connectivity. With a thorough spatial analysis and on-site visits, there was enough information to continue to the final phase and objective of this report: the recommendations.

The recommendations in this report come in two sets: preventative and corrective. The first sets of recommendations relate to preventative measures that will ensure a street network that is pedestrian- and transit- oriented for future urban developments. These are essentially policy recommendations that would structure how the construction of streets is governed and regulated. The second set of recommendations are

corrective, and therefore, responsive to the current condition of Nuevo Tocumen and 24 de Diciembre, but are relevant to neighborhoods throughout Panama.

Figure 3.3: Reference map with all five neighborhoods identified



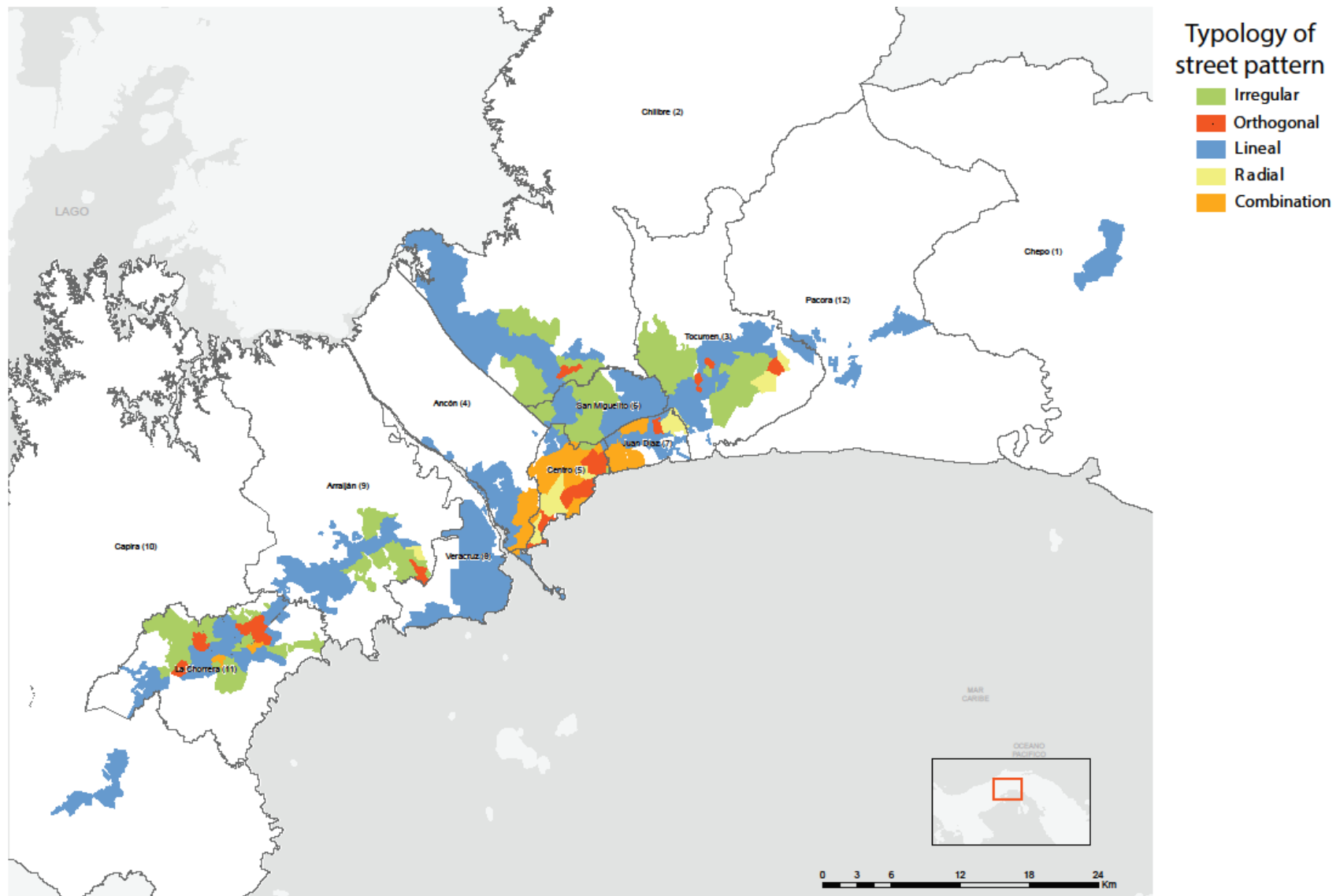
Chapter 4: Analysis

The general objective of this report is to formulate changes in the policies and regulations that currently govern and generate the street network of the AMP. The changes are meant to adjust the street network's structure so that it contributes to the efficiency of a pedestrian- and transit-oriented mobility system. In order to formulate these changes, this analysis sets out to achieve a better understanding of the actual patterns of the street network and the degree to which it supports or frustrates the efficiency of the mobility system. First, the chapter examines the adequacy of the arterial street network. Based on the understanding that a coherent and robust arterial street network is necessary for a well-functioning mobility system, Panama suffers from an extreme deficiency of arterial roads. Secondly, to assess the degree of connectivity in the five representative neighborhoods, three evaluations were performed. Collectively, these evaluations revealed that the AMP's street network is deficient due large blocks along arterial roads, prevalence of cul-de-sacs and/or dead-end streets and virtually no connections between adjacent neighborhoods.

4.1 Introduction to the Five Representative Neighborhoods

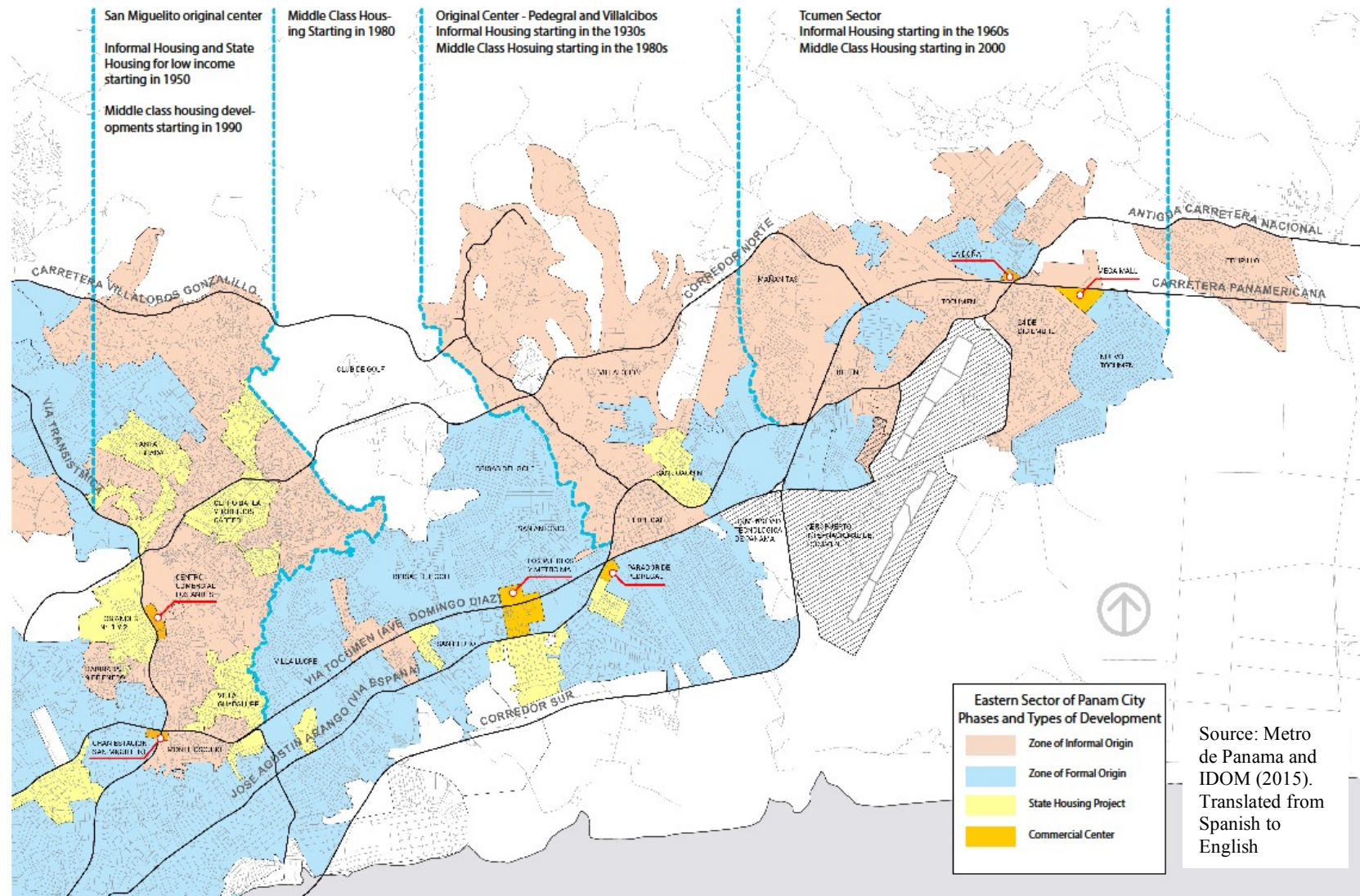
The street networks of the five representative neighborhoods differ from one another, each offering a unique insight into the pattern of development throughout the metropolitan area (Figure 4.1). This reflects the fact that some neighborhoods grew informally or organically overtime, while others were formally planned. Metro de Panama and IDOM (2015) and Uribe (1989) make the argument that development has occurred throughout the metropolitan area in a certain order; informal land invasions are followed by government provided services, which then facilitates the development of middle-class housing projects. This pattern of growth is illustrated in Figure 4.2. Metro de Panama and IDOM (2015) discuss the growth patterns found in the eastern portion of the metropolitan area that will soon be serviced by metro line 2. This area includes Villa Lucre, 24 de Diciembre and Nuevo Tocumen. This section gives a brief background history on the five neighborhoods, which will then lead into the spatial analysis and a discussion of the on-site visit. Villa Lucre will be analyzed independently, but Arraiján Central and Lomo Cobá, as well as 24 de Diciembre and Nuevo Tocumen will be paired due to their close proximity.

Figure 4.1: Typological map of street network patterns throughout the AMP



Source: Pimus: Gobierno Nacional de Republica de Panama (Panama)

Figure 4.2: Pattern of development on the eastern sector of the AMP. As can be seen, once informal settlements had been established, the government would provide services, which set the stage for private sector actors to develop middle class housing projects.



4.1.1 Arraiján Central & Lomo Cobá

While the jurisdiction of Arraiján is quite large, the area of study for this report is approximately 10 km². This makes population estimates difficult since the Census defines the area differently. Nonetheless it is clear that the area has had rapid growth in the population and built-up area since the 1980s as can be seen in Figure 4.3 below. From the original town center the area has grown in the southeastern direction organically through informal land invasions. Once portions of the Canal Zone were handed back to Panama from the United States, it was quickly settled upon by migrants. As can be seen in Figure 4.3, between 1986 and 1997 the built area grew dramatically and formed the shaped that exists today. While formal subdivisions have been increasing their share of new housing in the surrounding area, new growth within the study area is predominantly informal and makeshift housing, disconnected from formal infrastructure such as roads, water piping and sewage. The images in Figure 4.4 show informal settlement growth on the southern tip of the existing built-up area from 2009 to 2017.

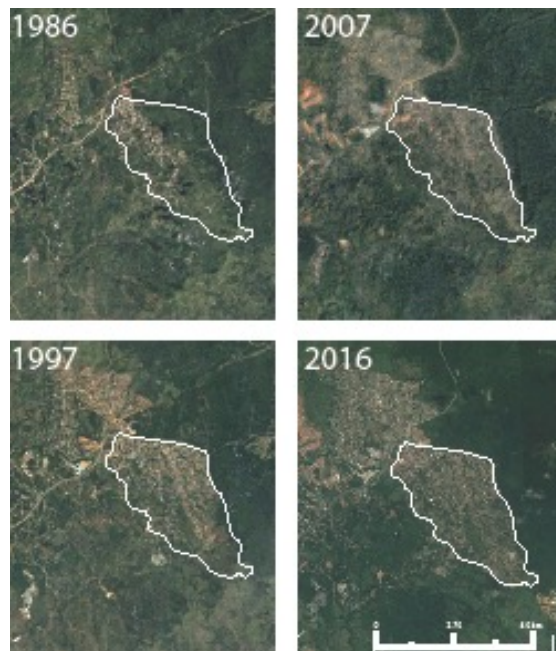


Figure 4.3: Physical growth of Arraiján Central and Loma Cobá (1986 – 2017)

White line represents present borde

Figure 4.4: Informal Growth in Arraiján 2009- 2016



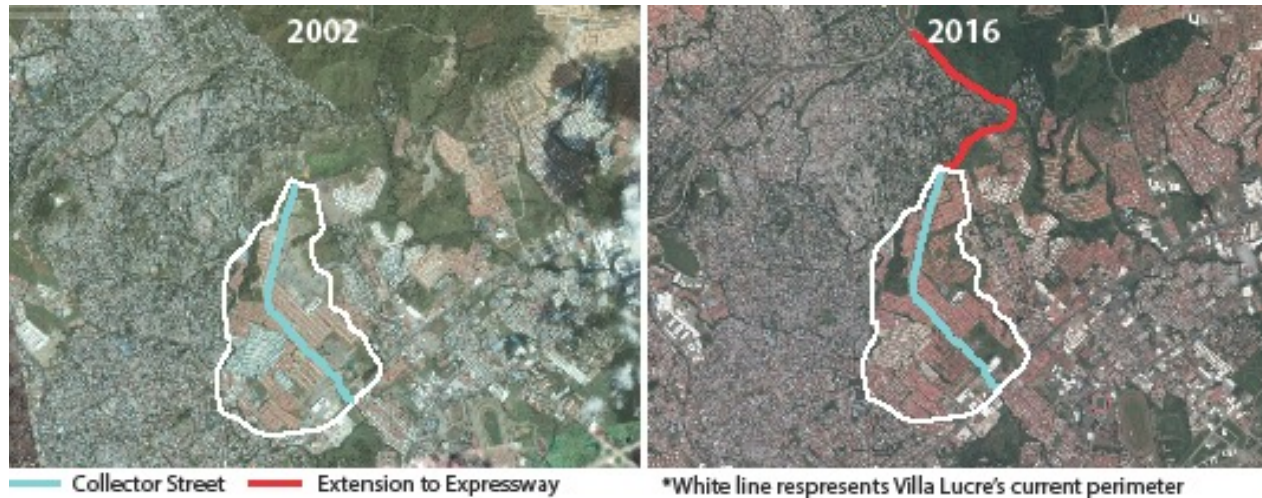
4.1.2 Villa Lucre

Villa Lucre was a planned development built between 1985 and 1986 by Grupo Cusa. Like many formal subdivisions in Panama, it trailed the growth of San Miguelito, Panama's largest informally built settlement. The massive growth of San Miguelito forced the government to improve services and accessibility to the area, thus leading to the formal development of adjacent land. Villa Lucre lacks any sort of formal connection to San Miguelito. Today, the entire area has been developed (Figure 4.5). The main road running through Villa Lucre, which originally led nowhere, has now been extended to connect the Pan American Highway to the new Corredor Norte (Figure 4.6). However, once out of the neighborhood, the road practically becomes an expressway since there are no entrances or exits until the Corredor Norte. According to the 2010 census the district had a population of 14,971, living in 5,500 houses (La Prensa, 2013).

Figure 4.5: Physical Growth of Villa Lucre



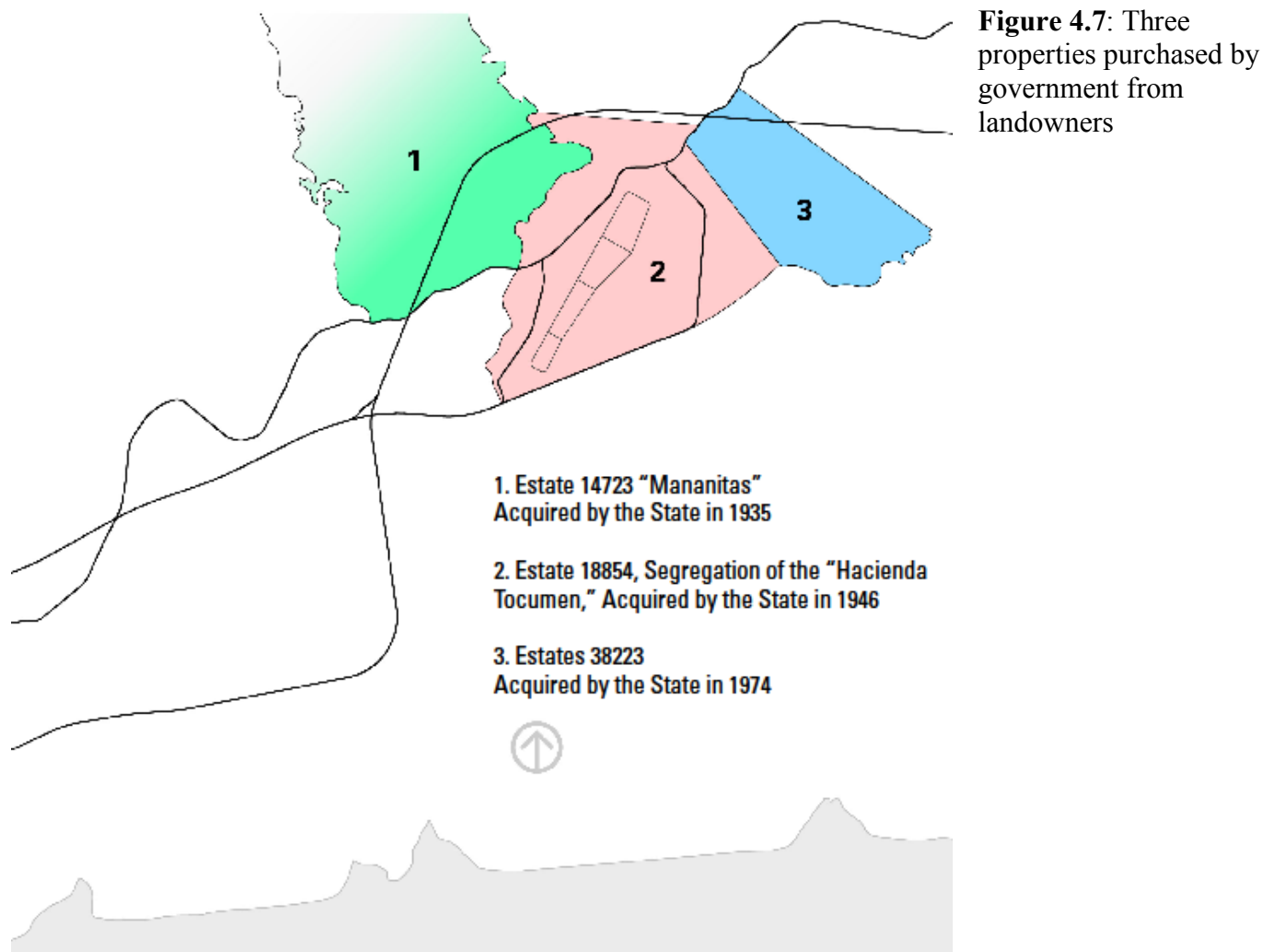
Figure 4.6: Extension of collector road to Corredor Norte



4.1.3 Nuevo Tocumen and 24 de Diciembre

The neighborhoods of 24 de Diciembre and Nuevo Tocumen are located in the eastern portion of Panama City. The highway, Carretera Nacional, was constructed to connect eastern townships to the central city in the 1920s. A couple decades later, construction began on the Tocumen International Airport and began operations in 1947, which further encouraged growth east of the central city. The land for which the airport was built upon was acquired by the government in 1946, but airport operations were mostly confined to the central zone of the property (Fig 4.7, pink area #2). Once the airport was built, there was plenty of unused land within the property's boundaries. By 1980, the land around the airport was fully occupied by rural migrants (Figure 4.8). Adjacent to the airport, the government bought another private farm in 1974 to begin a sugarcane operation (Figure 4.7, blue area #3). However, the plan was abandoned a few years later and the land was settled upon by squatters. Before, the entire plot had been settled; about half of the property was sold to a private buyer in 1983 (Figure 4.8). At this point the surrounding land was all privately owned so informal land

invasions ceased, at least in terms of surface area. The area that was sold in 1983 was developed as a middle class neighborhood in 2000s, now known as Nuevo Tocumen, and completely encloses 24 de Diciembre on the Southern and Eastern sides. Growth of the built-up area over the last four decades can be seen in Figure 4.10.



Source: Metro de Panama and IDOM (2015). Translated from Spanish to English

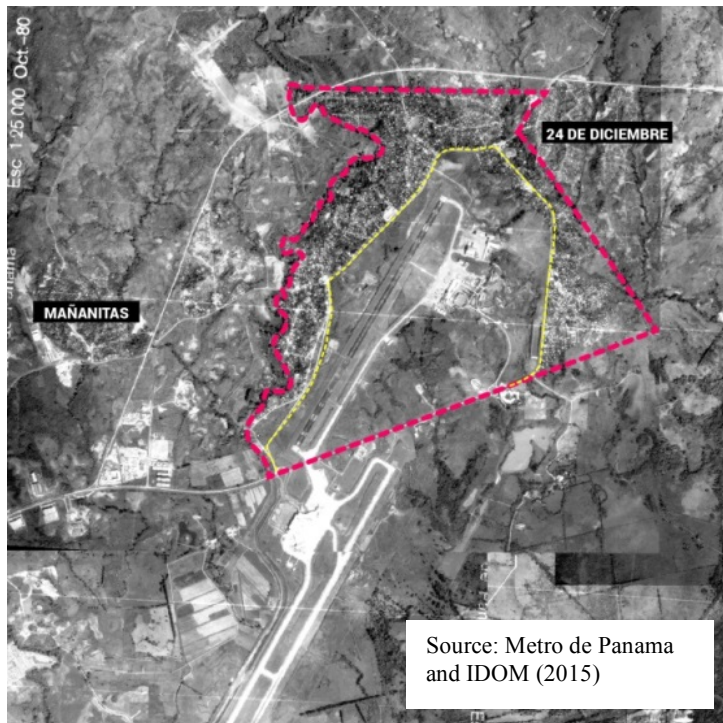


Figure 4.8: Original perimeter of the property on which the airport was built (pink line). The government built a road to keep settlers from settling further in (yellow line). Photo from 1980



Figure 4.9: Portion of land sold to private buyer

Source: Metro de Panama and IDOM (2015).



Figure 4.10: Physical growth of 24 de Diciembre and Nuevo Tocumen (1987 – 2017)

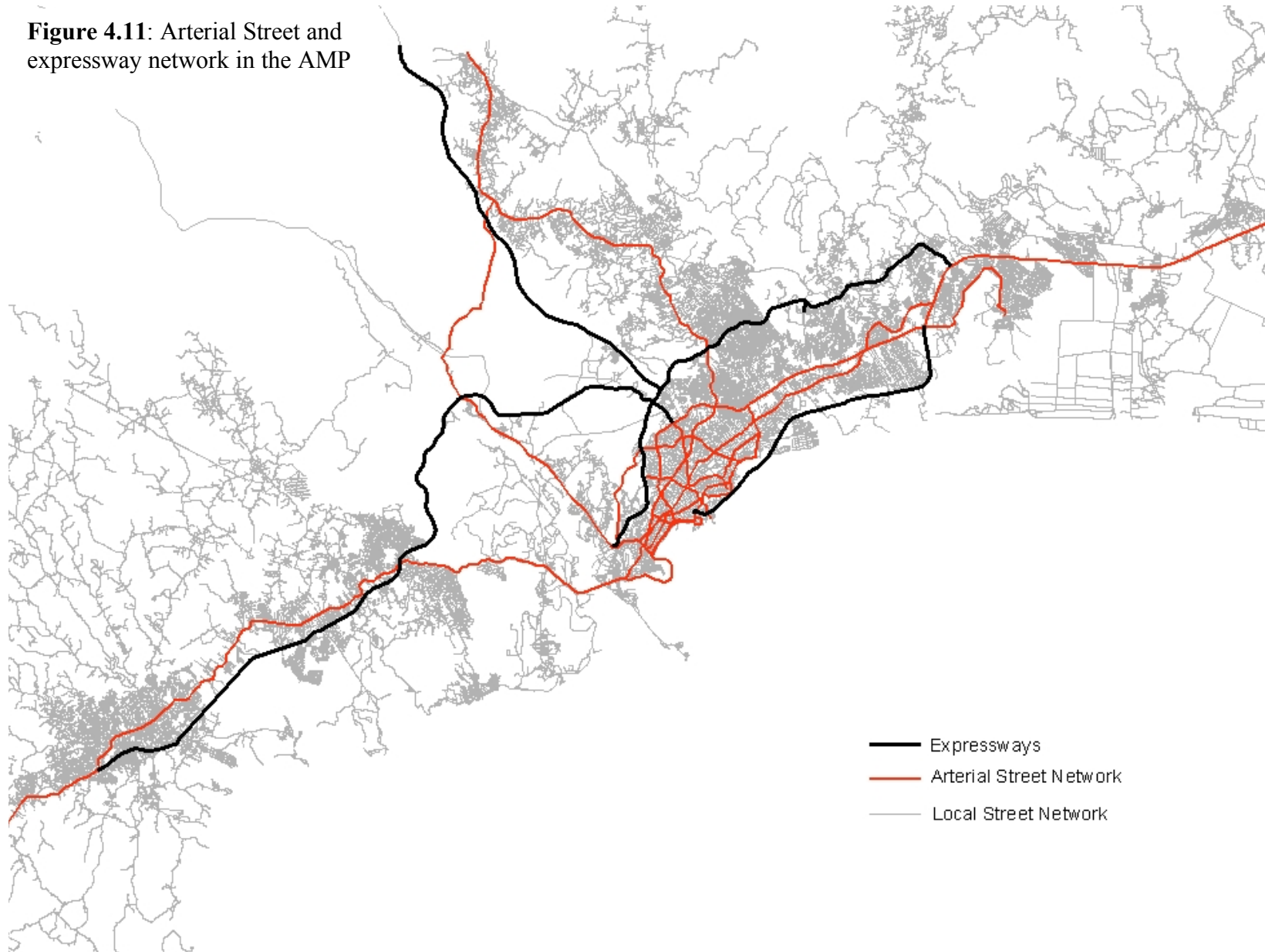
4.2 Spatial Analysis

4.2.1 Evaluation of Arterial Street Network

At the regional level, the absence of a regional network of arterial roads that connect areas of high activity to one another and carry public transportation routes is problematic. Angel (2012) recommends that expanding cities should plan for 20-30-meter-wide right-of-ways for arterial streets spaced at 1 km intervals. As mentioned earlier, Houston and many other cities in the United States have implemented 1.6 km (1 mile) arterial grids. While considerably larger than what Angel (2012) suggests, these superblocks offer flexibility and the potential to coordinate mobility orthogonally, which simplifies the system and theoretically limits any single origin-destination trip to the max of one transfer.

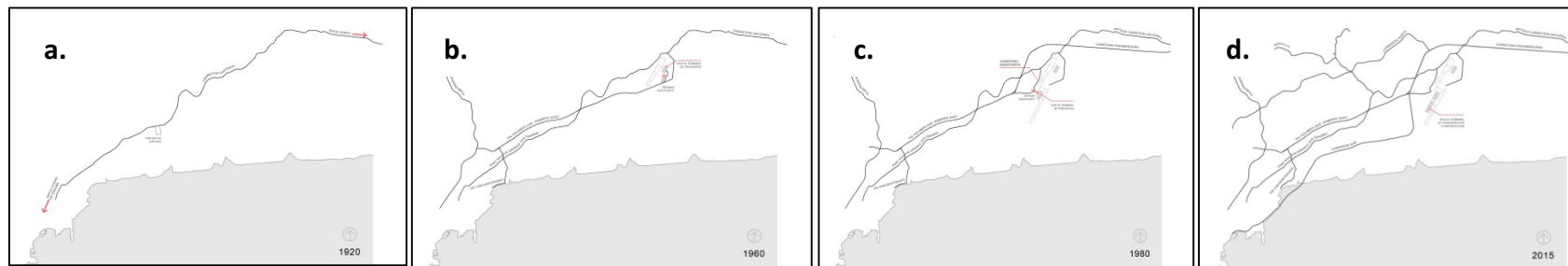
Assuming that a highly connected arterial road network carries public transportation routes throughout, it would guarantee that 100% of people in the city had access to public transit within walking distance. This would also mean that any location could be accessed by foot, without the need of a vehicle. It is important to keep in mind that having a highly connected network of arterial roads does not guarantee transit will be adequate or efficient, but it does leave space for it. As noted in the literature review, arterial roads in Panama have been neglected and poorly substituted by the expansion of the expressway network (Figure 4.11).

Figure 4.11: Arterial Street and expressway network in the AMP



The first road built from the city outwards, towards the east was built in 1920 (Figure 14.12a). A few years after the airport began operations, another road, the Avenida Domingo Diaz, was completed in 1954 and gave quicker access to the airport. Before this, in 1942, the U.S. Government built the Carretera Transistmica connecting Colón to Panama City (Figure 14.12.b). As the airport grew in capacity, Avenida Domingo was split and the present Pan-American Highway was built which acts as the northern border of 24 de Diciembre and Nuevo Tocumen (Figure 14.12c). Since the 1980, only one road has been widened into an arterial road (Carretera Villalobos Gonzalillo). Two expressways (Corredor Sur, Corredor Norte) have been built as well. However, access is restricted (toll of \$1.40 for private automobiles) and they serve the purpose of facilitating regional mobility. These expressways enable car-dependent development at the entrances and exits (Metro de Panama and IDOM, 2015). The western portions of the metropolitan region (Chorrera and Arraiján) are in an even direr situation since only one arterial road and one expressway connect them to the central city only. Some cities have either managed to extend their network of arterial roads effectively in the wake of new urban growth or kept growth along preexisting arterial roads; however, for the most part the provision of arterial roads has not kept pace with urban extent growth (Angel, 2016b).

Figure 4.12: Evolution of the Arterial Street and expressway network in the eastern portion of the AMP: (a); (b); (c); (d);



Source: Metro de Panama and IDOM (2015)

While there is not universal data on this matter, as mentioned earlier, Angel (2016a&b) and his team at the NYU Urban Expansion program¹ looked at a sample of 200 cities and found that cities are increasingly building new developments that are not within walking distance of an arterial road. In their study, they measured walking distance as 625 meters. According to the sample of 200 cities, 122 cities had 95-100% of the urban extent within walking distance of an arterial road. However, of urban areas built between 1990 and 2015, only 27 cities of the 200 cities had achieved such high proportions. Likewise, at the bottom end, before 1990, only 8 cities had less than 70% of the built-up area within walking distance of an arterial road. In areas built between 1990 and 2015, this number had grown to 32 cities. As can be seen in Figure 4.13, when performing a similar analysis on Panama, only 165 Km² or 38% of the Urban extent in Panama was within walking distance of an arterial road. Expressways were not included in the estimate, since they are not accessible to pedestrians. This is an astonishingly low number and the only cities within Angel's sample that are somewhat comparable are Berezniki, Russia, Singrauli, India, and Zhuji, China (Angel, 2016b). Figure 4.14 illustrates how the five representative neighborhoods might look based on the recommended spacing of arterial roads.

To be clear, Angel (2016b) and his team looked at the urban extent separately for the pre-1990 period and the period from 1990 to 2015. What is presented here (38%) is the percentage of the urban extent of Panama that is within walking distance (625m) of an arterial road in 2016. Furthermore, in this analysis a buffer zone was calculated around all arterial roads, meaning any built-up area that is within the Euclidean distance of an arterial is considered within walking distance. This includes areas that, due to the street layout, may not actually be within 625 meters of an arterial road, despite being within the Euclidean distance. If the actual walking distance was recorded, the percentage would be expected to be much lower. Therefore, it is difficult to make a direct comparison between our analysis and Angel's. Nonetheless, just from satellite imagery it seems clear that before 1990, a much larger proportion of Panama's built area was within walking distance of an arterial road.

¹ The NYU Urban Expansion Program, located at the Marron Institute of Urban Management and the Stern School of Business of New York University, in partnership with UN-Habitat and the Lincoln Institute of Land Policy initiated a multi-phase research project that monitors various aspects of global expansion.

Figure 4.13: Portion of AMP's urban extent within walking distance (625m) of an arterial road.

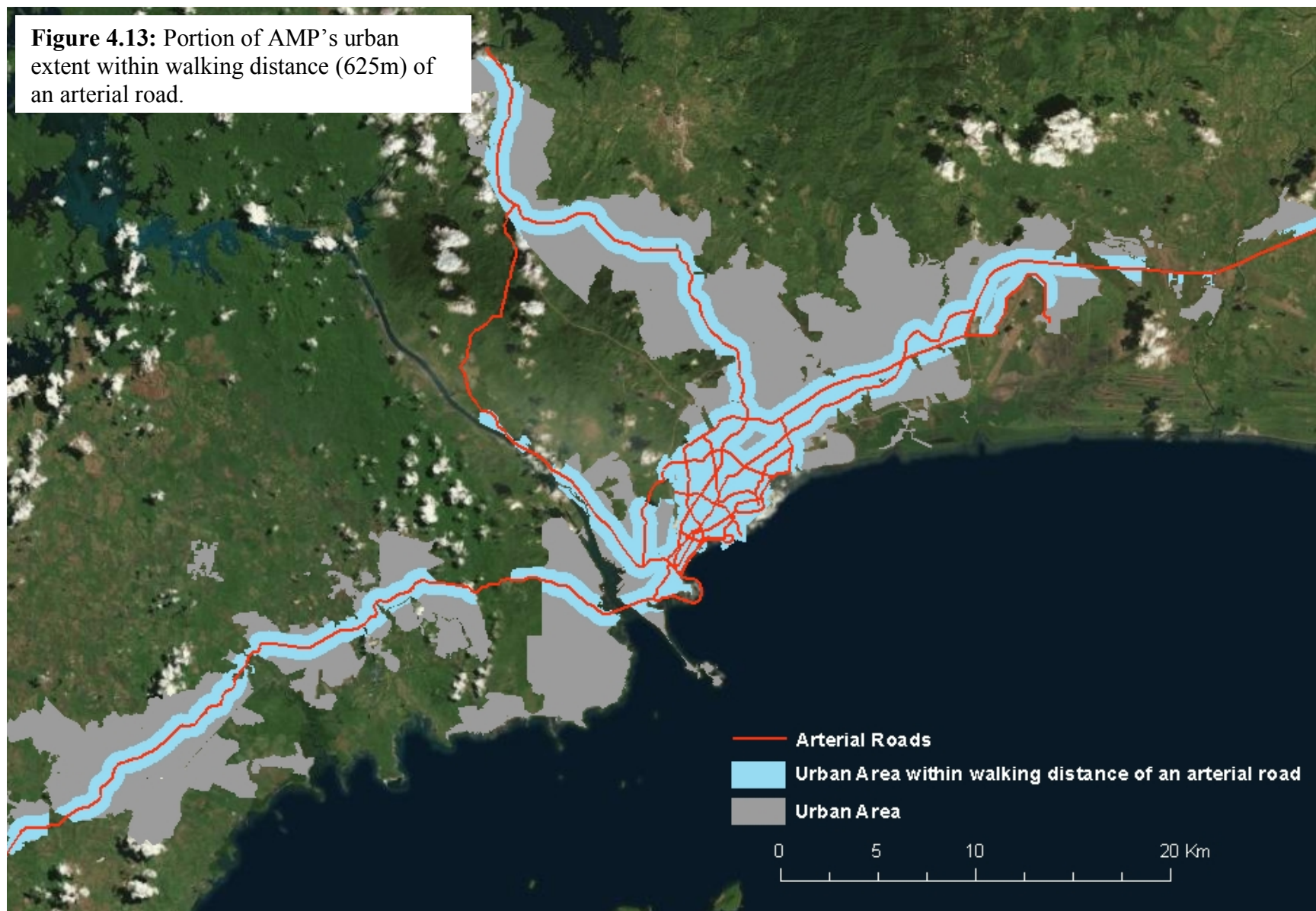


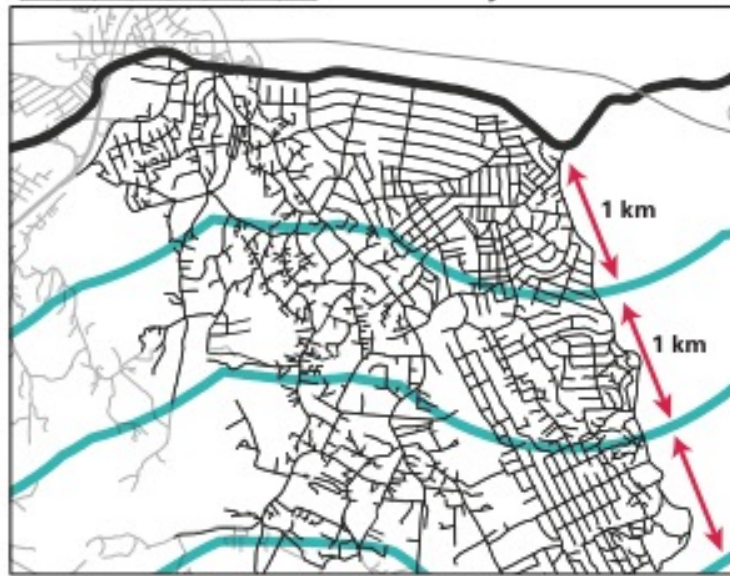
Figure 4.14: Hypothetical Spacing of arterial roads in the five representative neighborhoods

— Street Network
 — Other local roads
 — Existing arterial roads
 — Recommended arterial roads



0 0.5 1 2 Km

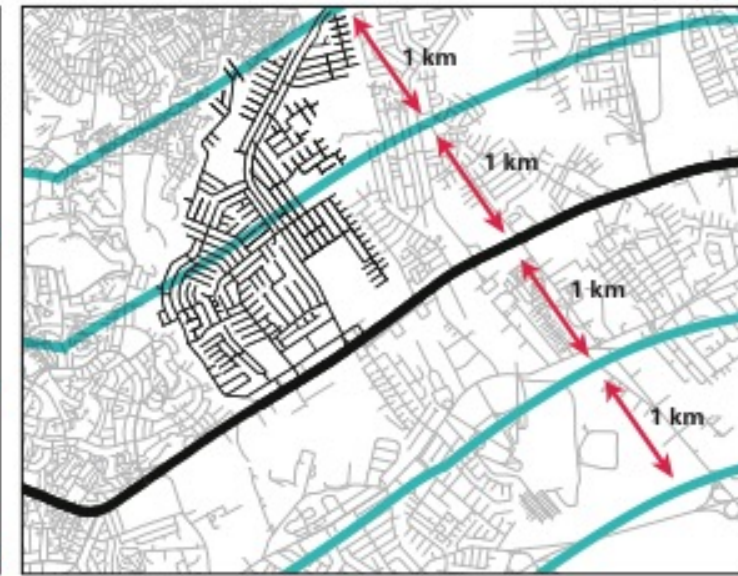
Arraiján & Loma Cobá



Nuevo Tocumen / 24 de Diciembre

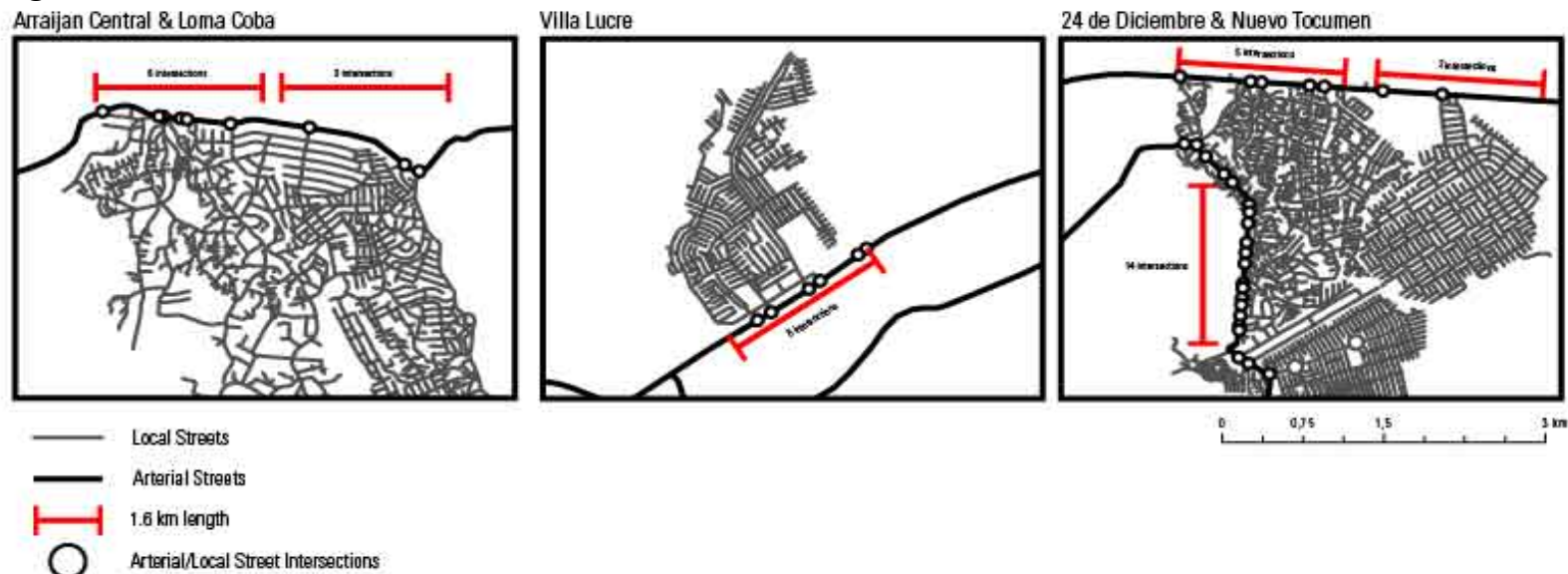


Villa Lucre



Referring back to the literature review, Kloster et al. (2000) found that for a well-connected street network that is pedestrian-oriented, the optimal range of connectivity along arterial streets is between 10 - 16 intersections per 1.6 km. However, a more conventional and automobile-oriented subdivision standard identified in *Urban Land Use Planning* (1995) states that primary arterial roads should have a minimum distance of 800m between intersection and secondary arterials should have a minimum distance of 400m between intersections. Each of the representative neighborhoods is located along an arterial road. Figure 4.15 below, displays the number of intersections between local and arterial streets. Street intersections that led to dead-ends, cul-de-sacs or parking lots were not included. In terms of spacing, there is no obvious pattern. The informal neighborhoods of 24 de Diciembre and Arraiján have provided more intersection than the planned neighborhoods of Nuevo Tocumen and Villa Lucre where very few collector or local roads lead into the neighborhood. It is evident from this exercise that the formally built neighborhoods were planned for the vehicle. The intersection spacing in the informally built neighborhoods is less clear and less consistent.

Figure 4.15: Number of intersections within 1.6 kilometers



*In some cases, the floating dots are where intersections occur on the other side of the street

From this analysis, two aspects of the street network in Panama are clear. First, there is a severe lack of arterial roads in the metropolitan region. This poses a problem because it forces greater numbers of vehicles to travel on a few roads in order to reach regional destinations. Secondly there is an obvious lack of connections between arterial roads and neighborhoods, especially formally-built neighborhoods such as Villa Lucre and Nuevo Tocumen. This means travelers and transit routes are forced to access arterial roads through fewer points. This undoubtedly mitigates through traffic almost entirely, but leaves pedestrians at a great disadvantage. The laws regulating subdivisions are clearly the reason for this type of development since they do not require new developments to connect to existing or planned neighborhoods.

4.2.2 Evaluation of Block Size

The size of blocks has numerous implications for mobility. As discussed in the literature review, small blocks encourage pedestrian activity. As a global trend, blocks have been growing in average size (Angel, 2016b). Figure 4.16 (Part 1 & 2) illustrates the evolution of block sizes in the metropolitan region. The five representative neighborhoods are shown in conjunction with other neighborhoods in the city. Included are Panama's three oldest neighborhoods: Panama Viejo (1519), Casco Antiguo (1673) and Colon (1850); and two neighborhoods planned and built in the first half of the 20th century: La Exposición (1914), San Francisco (1940).

Clearly, blocks have been getting larger overtime. Even Nuevo Tocumen, which has a grid-like structure, has an average block size that is nearly three times as large as Casco Antiguo. This trend is not unique to Panama. Angel et al. (2016b) report that average block size between urban areas built before 1990 and those built between 1990 and 2015 has increased by 51%. The principal difference found between informal and formal neighborhoods is that informally built neighborhoods have a large variation of block sizes. The exception to this is Villa Lucre, which has a road network much like that of 24 de Diciembre with large blocks produced by numerous cul-de-sacs. While neighborhoods designed like Villa Lucre are not common in Panama, Villa Lucre seems to fall into what Kristof (1991) referred to as “planned organicism” since it blurs the line between planned and organically grown street layouts. Geographic barriers, such as rivers and varied elevations acted as barriers to connectivity in 24 de Diciembre, whereas in Villa Lucre it was purposefully designed.

Figure 4.16: Part 1 - Evolution of block size in the AMP

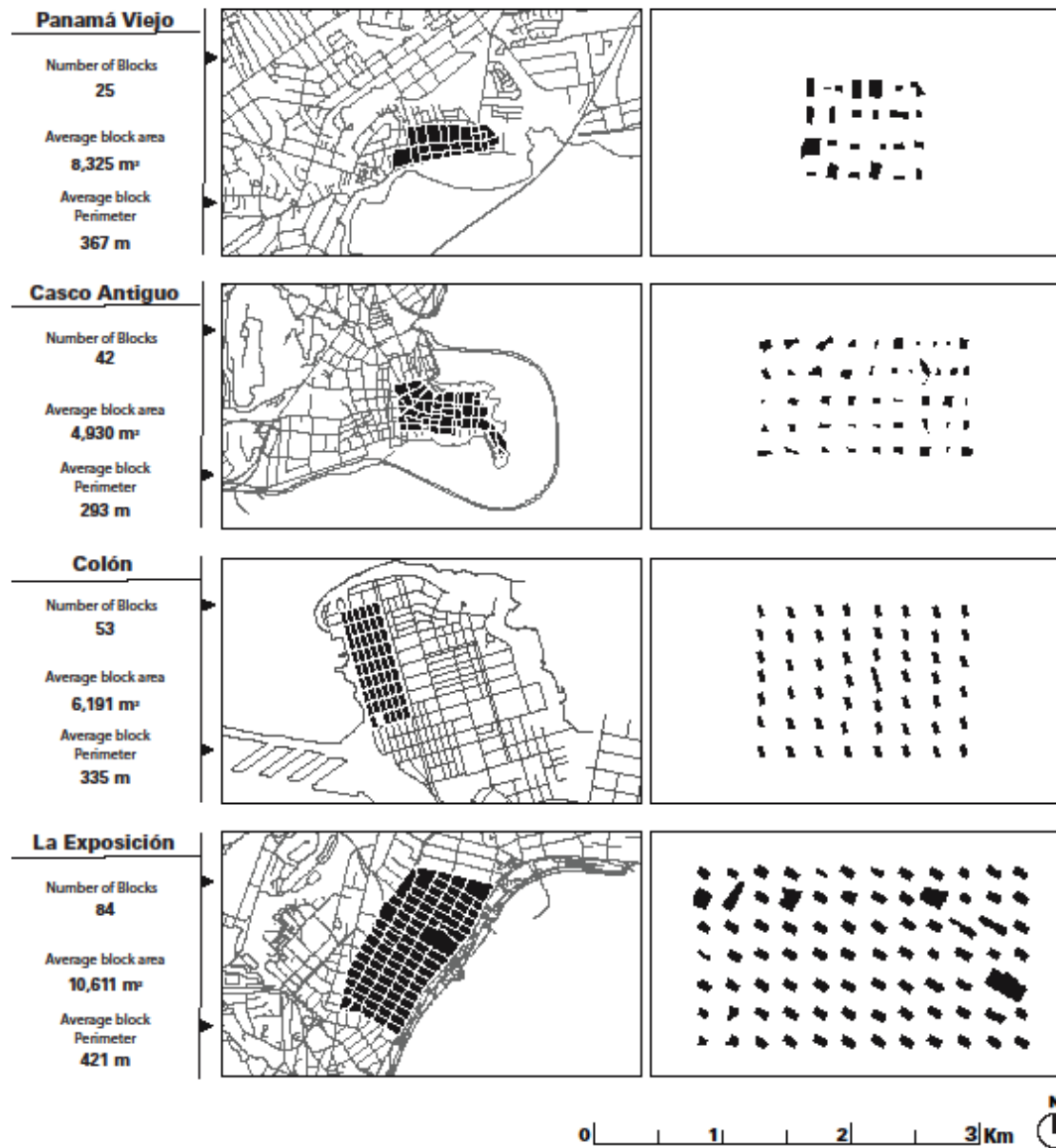
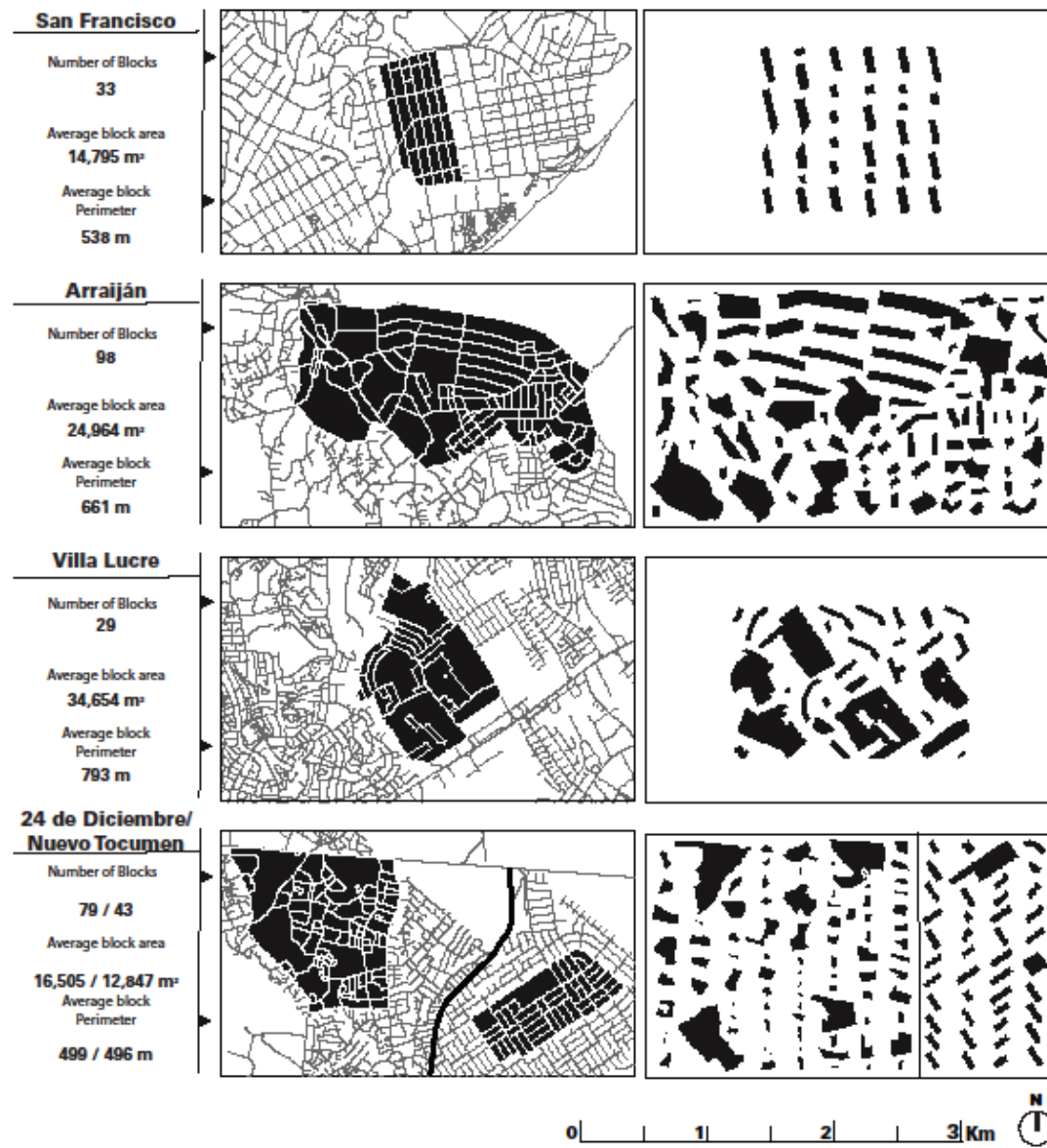
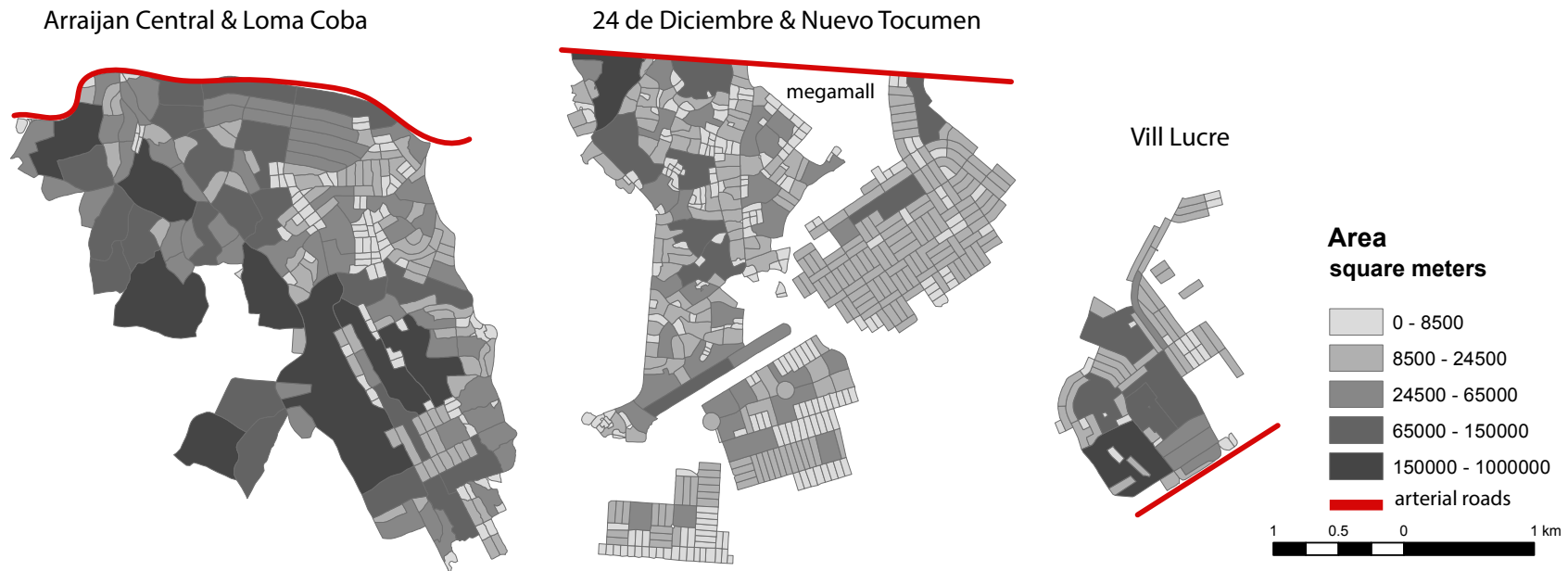


Figure 4.16: Part 2 - Evolution of block size in the AMP



In the five representative neighborhoods, blocks tend to be larger near the edges of the neighborhood, especially along arterial roads. This is likely due to large commercial properties, which are not forced to abide by block length requirements. This can be seen in Figure 4.17 below.

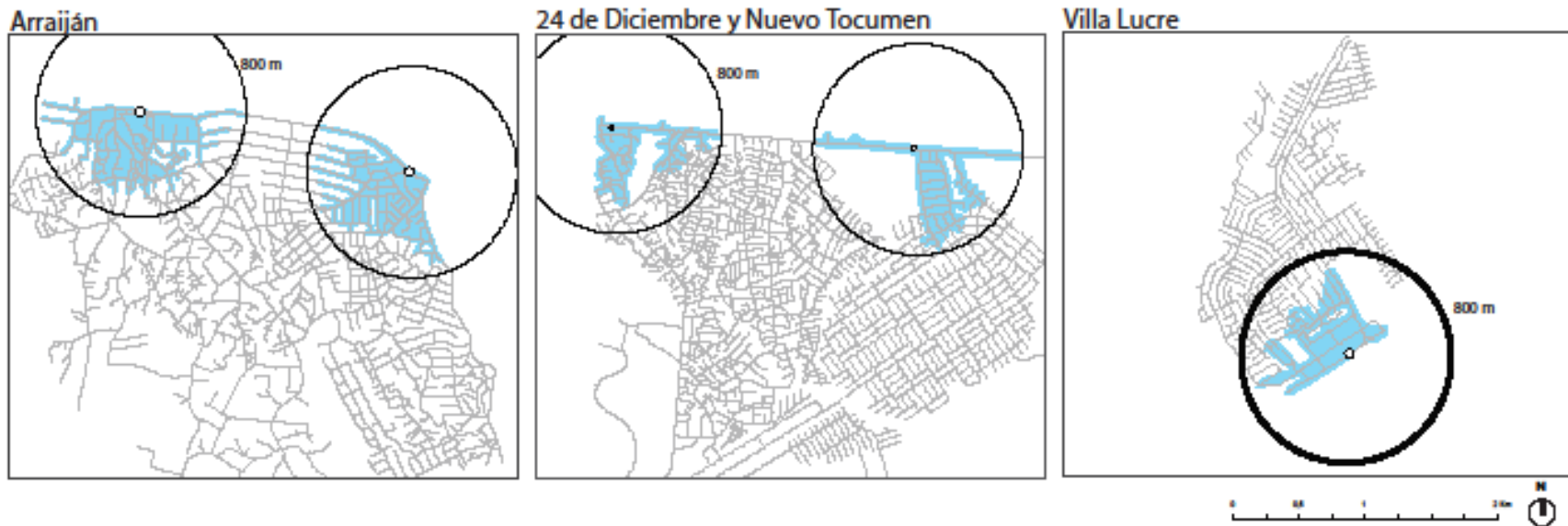
Figure 4.17: Variation of block size in the five representative neighborhoods



As mentioned in the literature review, smaller blocks create a more pedestrian friendly environment for numerous reasons. One of those reasons is that smaller blocks with frequent intersections should allow a pedestrian a more direct route from point A to point B. One of our principal questions in this report is; how supportive is the street network in Panama of a pedestrian- and transit-oriented city? It is reasonable to assume people will walk approximately 800m to a fixed-rail station. If a street network were “perfectly” effective then every individual within an 800-meter straight-line distance from the station could walk to a metro station within 800-meters or less.

To test the effectiveness of the street patterns in the five representative neighborhoods, an 800-meter catchment area was calculated for each neighborhood and compared to six hypothetical grid layouts ranging from very small blocks that are 30m by 30m to very large blocks that are 180m by 180m. Figure 4.18 and 4.19 illustrate the how certain street patterns can determine the extent of 800 meters. This extent is measured by surface area and kilometers of streets. The results can be easily compared in Figure 4.20. In Figure 4.19, the coverage areas are displayed with a radius of 800 m around a hypothetical public transit station. When increasing the size of the blocks, the linear meters of streets captured within an 800 meter catchment area is reduced. It is evident that each street network performs poorly when compared to even the largest grid made of 180 by 180 meter blocks. Of the all the neighborhoods, Arraiján Central performs best, and actually outperforms the 180m by 180m block in linear kilometers of streets captured by the catchment area.

Figure 4.18: 800-meter catchment area of metro stations



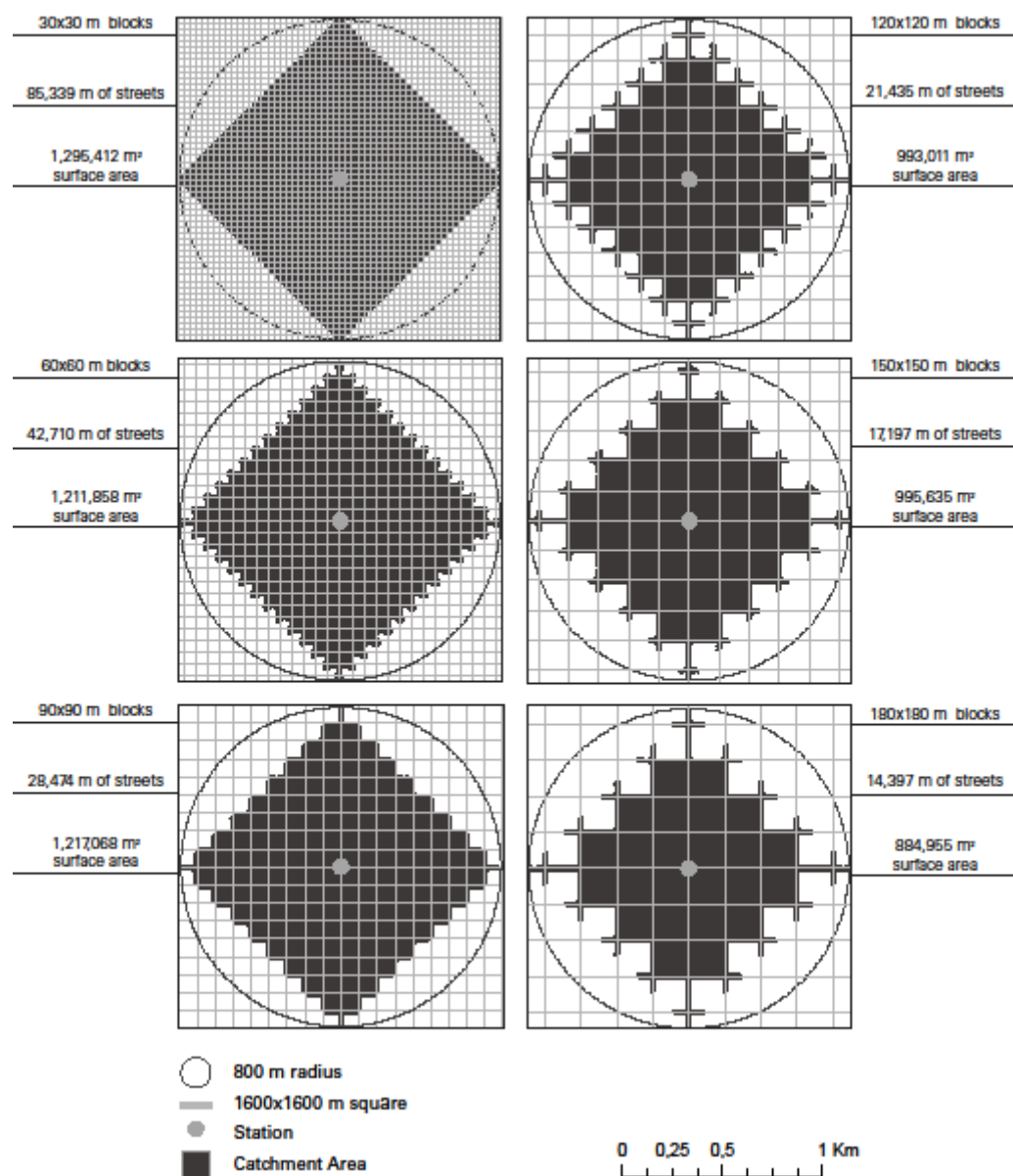


Figure 4.19: 800-meter catchment area of transit stations centered in theoretical grids

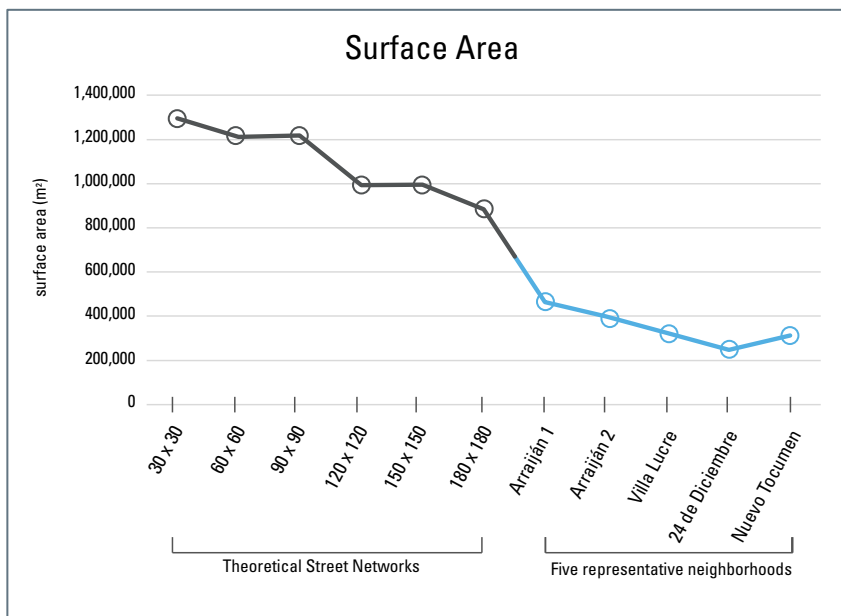
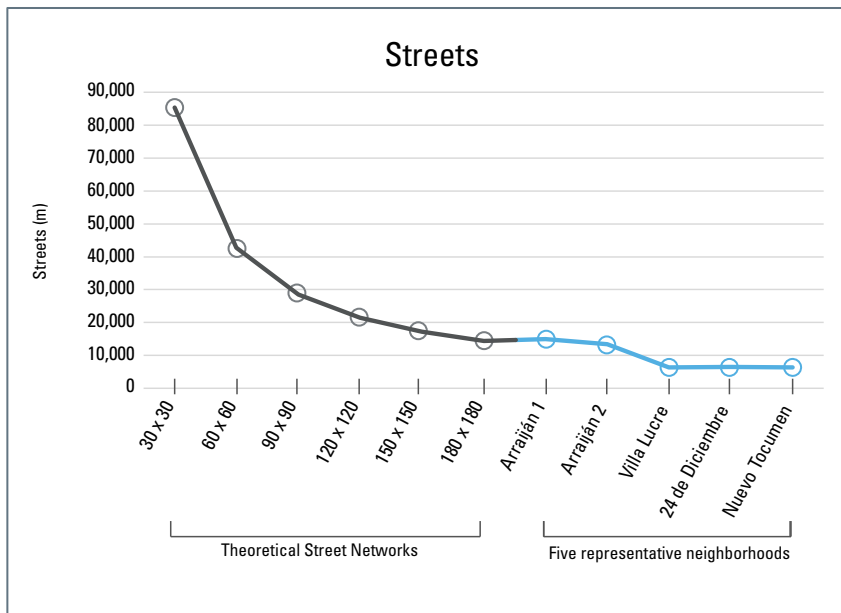
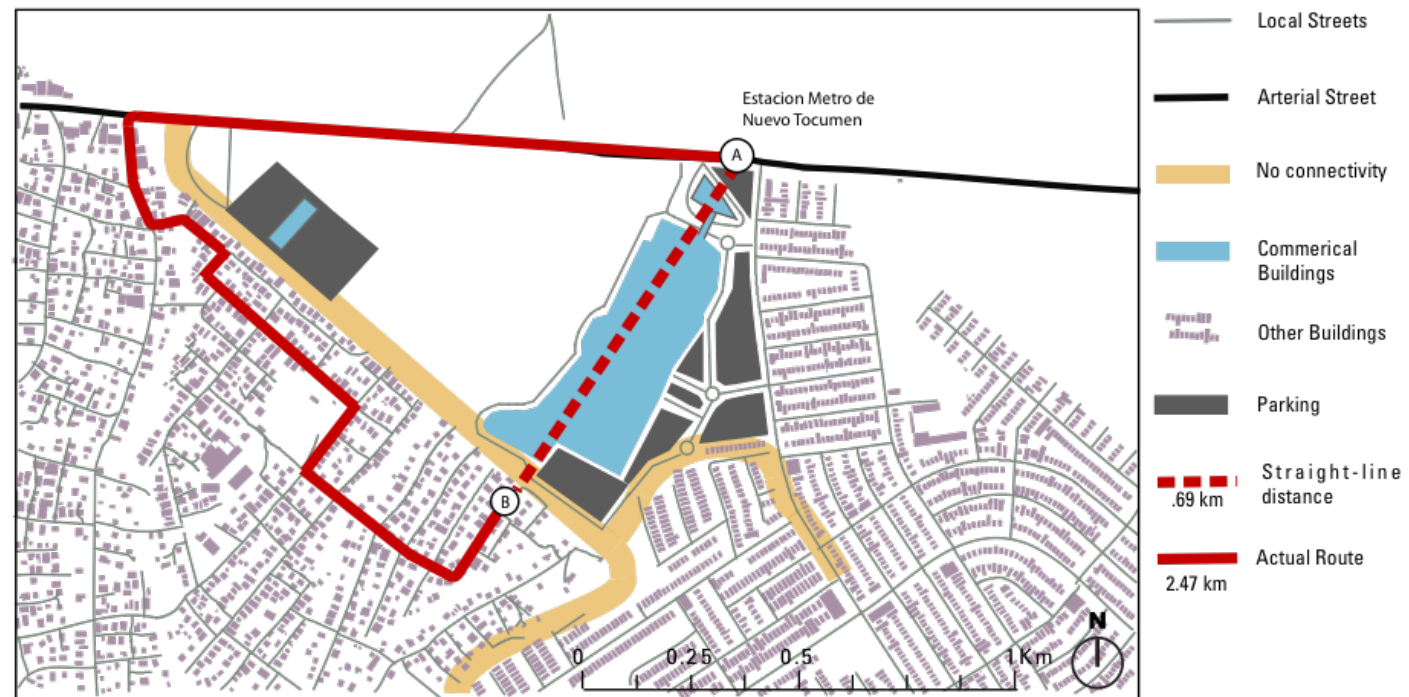


Figure 4.20: Results from Figure 4.17 and 4.18. Surface area and linear meters of street captured by an 800-meter catchment area for theoretical grids and the five representative neighborhoods

Two principal factors regarding block size are responsible for the poor performance of the street network. First, large blocks near the station (i.e. near the arterial roads) require pedestrians to take indirect routes. This also results in large gaps between intersections along arterial roads. This is very obvious when looking at Nuevo Tocumen, 24 de Diciembre and Villa Lucre. Figure 4.21 below illustrates this problem in Nuevo Tocumen. Secondly, a proliferation of dead-ends in Arraiján, Villa Lucre and 24 de Diciembre stop the 800-meter path from continuing far before it has reached 800 meters in length. In one case in Arraiján Central, a dead-end stops the 800-meter path after only 615 meters (Figure 4.22). This underperformance results in 185 meters of lost distance.

Figure 4.21:
Example of the deficiency of the street network caused by large blocks (Nuevo Tocumen)



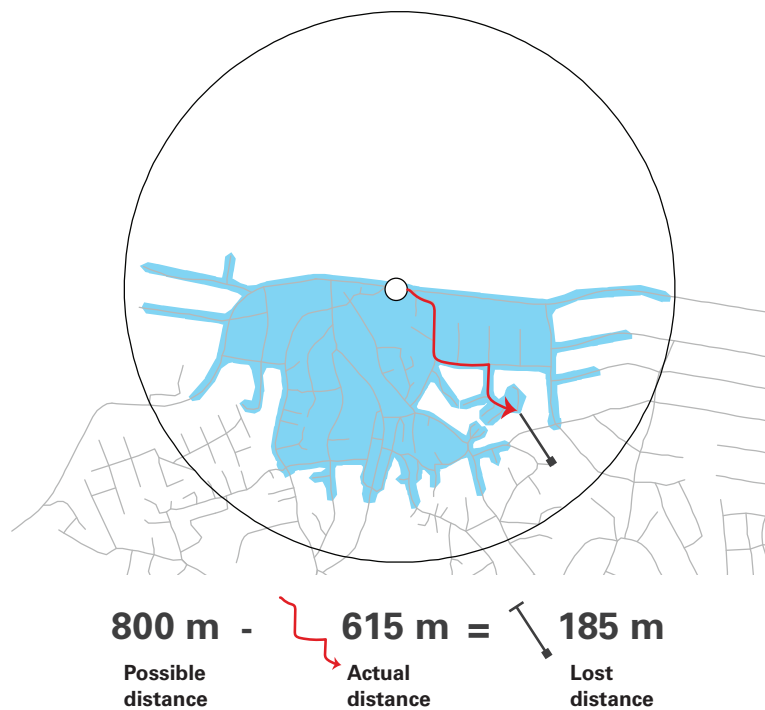


Figure 4.22: Example of the deficiency of the street network caused by large blocks (Nuevo Tocumen)

4.2.3 Evaluation of Pedestrian Route Directness (PRD ratio)

A common and relatively dependable method for assessing the ease of pedestrian movement is the pedestrian route directness ratio (Stangl, 2012). To find this ratio, the Euclidean distance from every intersection within an 800-meter radius of the metro station was divided by the shortest distance path along the street network. Anything outside of the 800-meter radius was not included since pedestrians in these areas are more likely to take a bus or drive to the metro stations. A one-to-one ratio is optimal, but only possible if straight roads radiate directly from the station. In theory, a higher ratio indicates a less efficient the street network. However, distance manipulates the ratio so in order to make comparisons, a specific destination point must be chosen and the points of origin must all fall

within a predefined radius of the destination point. In this report, intersections are the selected points of origin on which the analysis is based and metro stations are the destination points. While this is not as accurate as points selected for each individual lots or buildings, it is easy to replicate for multiple stations and only a street network shapefile is needed. This ratio can be extremely valuable to city planners who would like to identify specific areas that display low levels of connectivity. Once identified and a desired maximum ratio is established, corrective solutions are quite straightforward.

In Figure 4.23, the ratios for each metro station in the five representative neighborhoods were calculated. Arraiján Central and Loma Cobá had the lowest scores indicating that residents of those neighborhoods who live within an 800-meter radius of the future metro station site will, on average, have a 1.38 (Loma Cobá) times and 1.51 (Arraiján Central) times further distance to the station than the straight line distance. Nuevo Tocumen exhibits the most extreme case where, according to the formal street network, residents must walk around two times the distance. An obvious indicator of the inefficiencies of the network is when the necessary route forces a pedestrian outside of the 800-meter radius. This is seen in Nuevo Tocumen and Villa Lucre most clearly. For comparison, PDR ratios were calculated for two hypothetical street networks (Figure 4.24). The first is a perfect grid with 100 by 100 meter blocks. The second is the same grid, but with two streets running diagonally in four directions. The first grid achieves a PDR ratio of 1.27. In fact, all grids, regardless of block dimensions have the same PDR ratio within an 800-meter radius. The second street network with diagonal streets has a PDR ratio of 1.05, which is nearly a 1:1 ratio. According to UN-Habitat (2013) a PDR ratio of 1.5 or lower is necessary for a walkable environment.

Figure 4.23: Pedestrian Route Directness Ratio for the five representative neighborhoods

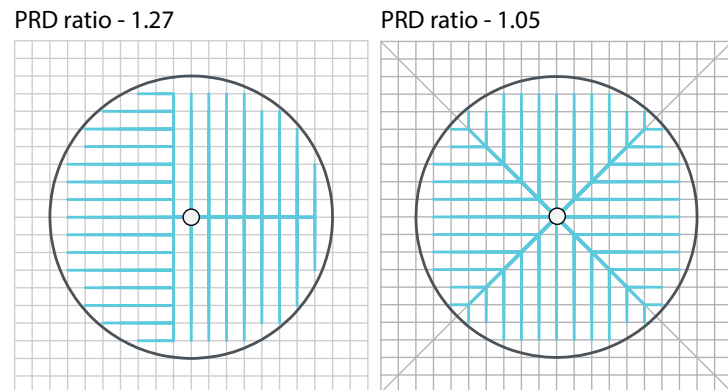
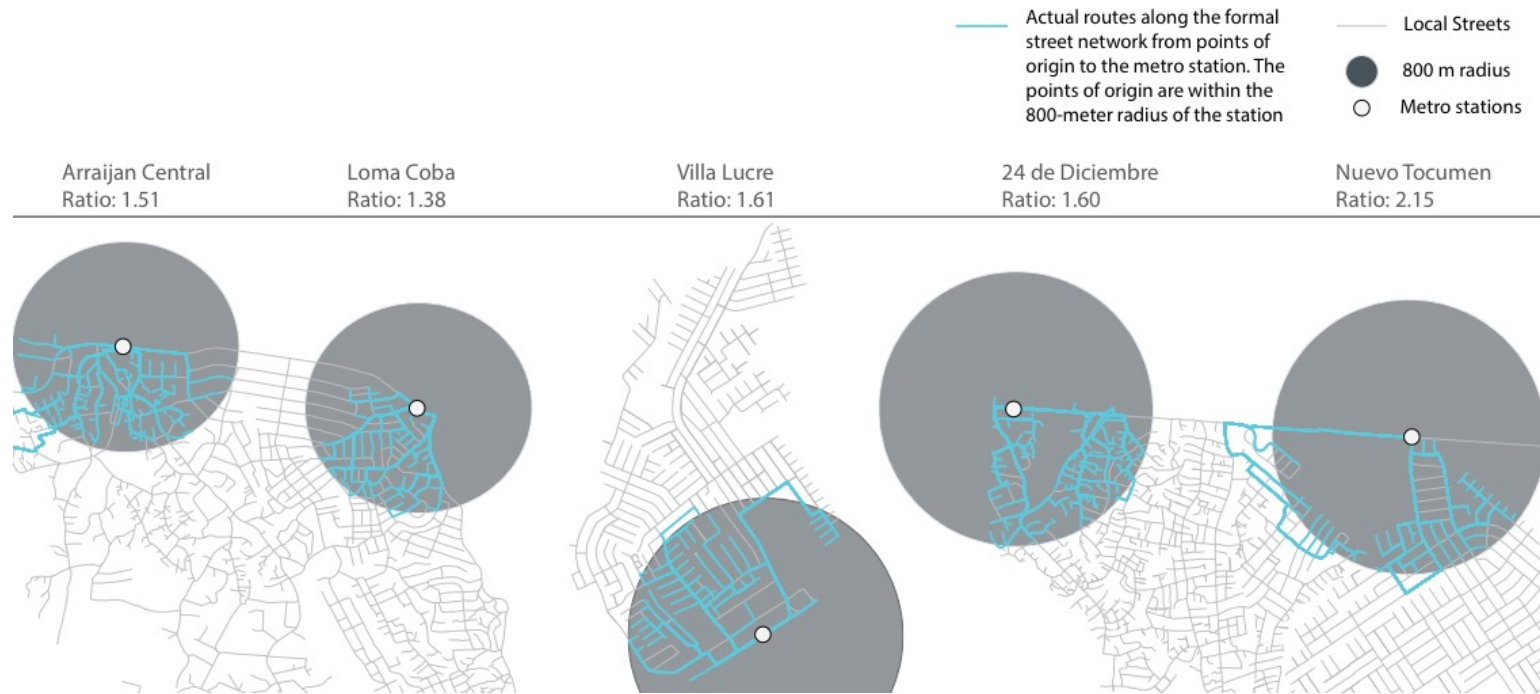


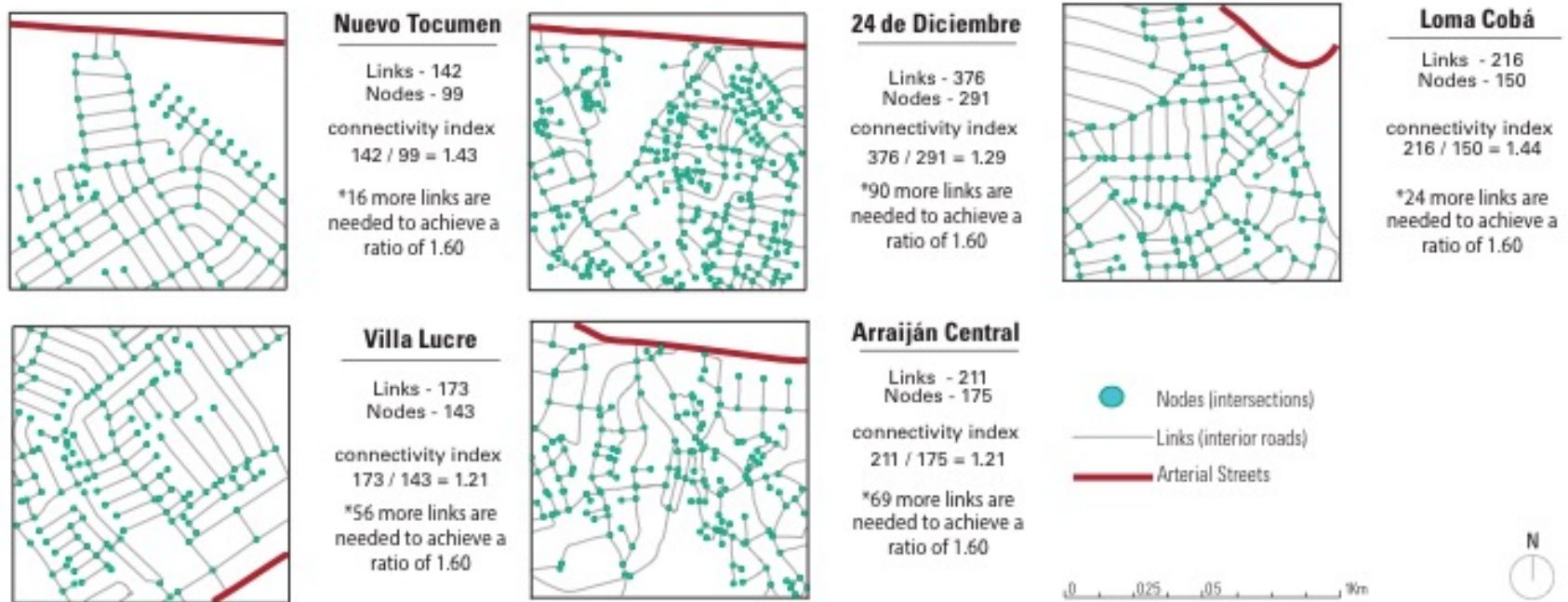
Figure 4.24: Pedestrian Route Directness ratio of two theoretical street networks within an 800-meter radius.

- 1). 100 by 100-meter block.
- 2). 100 by 100-meter blocks with two diagonal streets

4.2.4 Evaluation of internal street connectivity (Link-To-Node)

Another method for assessing street connectivity is the link-to-node ratio. As discussed in the literature review, this ratio identifies areas where cul-de-sacs and dead-ends disrupt the connectivity of the neighborhood. The index can be calculated in different ways, but in this exercise the goal is to understand the impact cul-de-sacs have on internal street connectivity. Therefore, connections between local arterial streets were not included. As can be seen in Figure 4.25, the neighborhoods of Nuevo Tocumen and Lomo Cova have the highest ratios at 1.43 and 1.44 respectively, while 24 de Diciembre and Villa Lucre have the lowest scores. Again, the street network of Villa Lucre truly blurs the lines between formally planned and informal neighborhoods. This index is generally used to guide new development, but it can also be used to understand how cul-de-sacs and dead-ends impede a neighborhood's connectivity. Planners can then aim to improve connectivity by increasing links and decreasing nodes to an acceptable level. For example, in Arraiján Central, a link-to-node ratio of 1.60 can be achieved by adding 69 links or decreasing nodes by 44 or a combination of both. This allows a degree of flexibility for developers and planners, but does not guarantee connections are made where needed or in a way that promotes a pedestrian friendly city. For example, a 180m by 180m grid is not necessarily friendly to pedestrians, but it would score very high on the link-to-node index.

Figure 4.25: Link-to-Node ratios of a 1km section in the five representative neighborhoods



4.2.5 Issues Raised

From the spatial analysis a number of factors emerged that help to characterize the street network pattern of the Panama Metropolitan Area:

- Insufficient arterial roads
- Insufficient number of connections to arterial roads
- Poor or no connectivity between neighborhoods
- Large blocks located along arterial roads
- Pedestrian route directness varies between neighborhoods, but is generally poor
- Internal street connectivity is acceptable

These factors are further explored in Section C of the analysis which discusses the on-site visit to 24 de Diciembre and Nuevo Tocumen. Due to limited time and resources, the onsite visit had to be narrowed and focused. To do this, “areas of poor connectivity” were identified, which in turn directed the on-site visit. These can be seen in Figure 4.26. The “areas of poor connectivity” were identified based on the spatial analysis and are grouped into three main categories: (1) areas characterized by large blocks, cul-de-sacs or dead-ends; (2) areas where geographic boundaries have limited connections; (3) areas between neighborhoods where no connections exist. Overlap between the three groups is considerable.

Figure 4.26: Areas of poor connectivity in 24 de Diciembre and Nuevo Tocumen.



4.3 On-Site Visit

4.3.1 Purpose

On Thursday, February 16, 2017 and Saturday February 24, 2017, two site visits were performed in the afternoon. The purpose of the site visits was to observe areas identified as “areas of poor connectivity” (Figure 4.26) in the study areas of 24 de Diciembre and Nuevo Tocumen. The Pimus Study (2016) identified the study area as having pedestrian infrastructure that was *escaso*, translated as “limited, scant, scarce.” It is reasonable to assume that scarce pedestrian infrastructure and poor street connectivity would discourage pedestrian activity; however, as stated at the beginning of this report, less than half of the AMP’s households own a vehicle, which leads to the assumption that a large portion of the population are pedestrians and/or transit users, despite inadequate conditions. This assumption is strengthened by the fact that the populations within these neighborhoods are not among high income echelons of the AMP. According to the 2010 Census, the average monthly household income in 24 de Diciembre and Nuevo Tocumen is between \$600 and \$1000 US, which represent lower-middle income households in the Metropolitan region. It is important to note that while the on-site visit was informative, it does not lead to any conclusive evidence on the travel behaviors of pedestrians. The objective was to understand the severity of disconnectivity and locate physical signs of how pedestrians in these neighborhoods have responded to poor connectivity.

4.3.2 On-Site Visit Findings

The results of the on-site visit are demonstrated below through a series of photos taken throughout the visit in the “areas of poor connectivity.” Figure 4.27 and 4.28 indicate the location of the photos and demonstrate how the geography, street patterns and man-made physical structures are linked together in these two neighborhoods.

Figure 4.27: On-Site visit reference map for Nuevo Tocumen and 24 de Diciembre

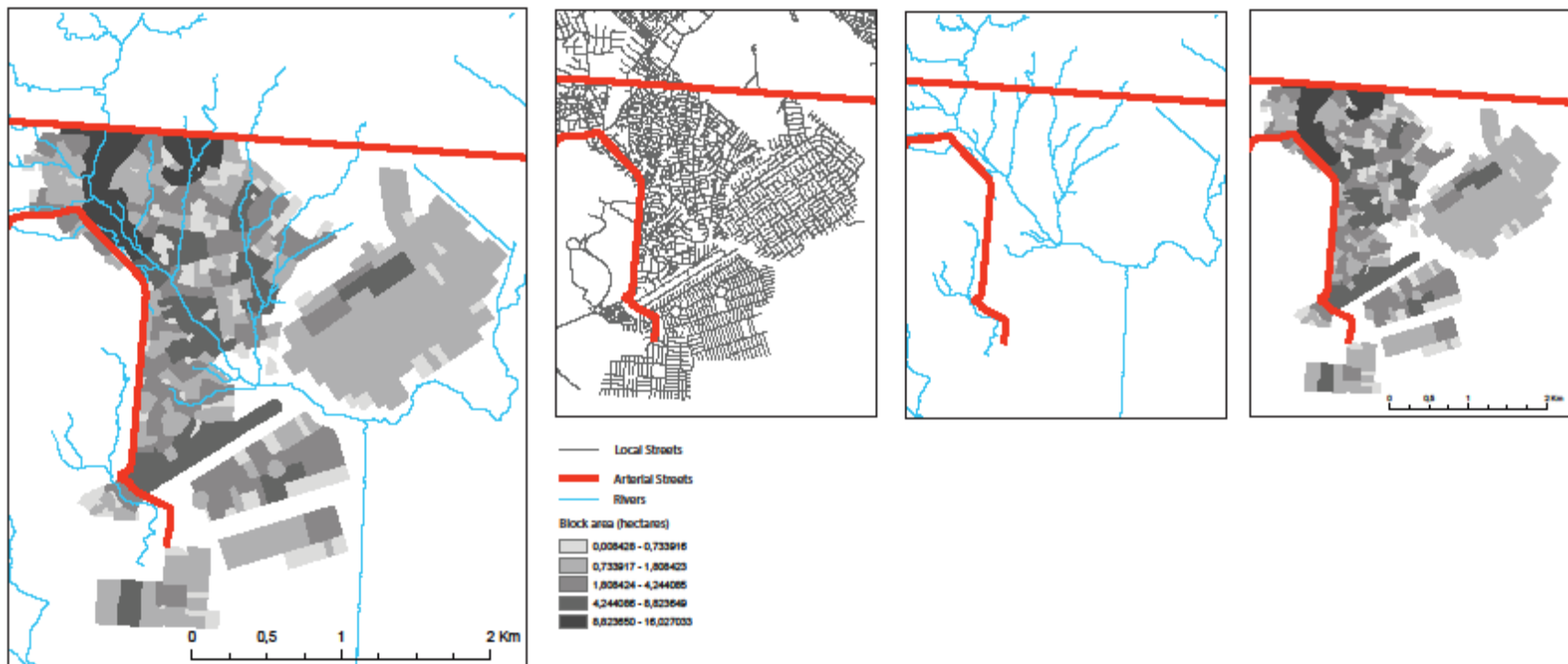


Figure 4.28: Location of photos from the on-site visit



As the analysis revealed, the megamall acts as a major access barrier for the area located with an 800-meter radius of the metro station in Nuevo Tocumen. The mall which covers approximately 15 hectares in surface area (building and parking) is wedged between the two neighborhoods. The mall was constructed on a large piece of land that had previously been empty. From the street network analysis, there appeared to be no connections between the mall's parking lot and 24 de Diciembre, but two connections to Nuevo Tocumen and one to the arterial road (Pan-American Highway). However, there are streets that stop at dead-ends at the mall's perimeter. The location of the future metro station will be located at the Pan American Highway's entrance to the mall's parking lot, making it the center of the station's catchment area. This is especially true because at the moment there is no development on the opposite side of the road. Satellite imagery was not clear enough to know rather or not pedestrians were able to access the mall directly from the surrounding homes, so the site visit was critical in better understanding how locals interacted with the new commercial center.

The first on-site visit uncovered that the mall's managers had gone to great lengths to block surrounding residents from entering the mall's premises directly. The reason behind this is unknown, but a few speculations can be made. For example, it is possible that the mall's management does not view the nearby residents as ideal clientele, they want people to only come in cars, or they believe that by limiting the number of entry and exit points they have a better control of security. Chain link fences had been erected along the borders of the parking lots where homes in 24 de Diciembre and Nuevo Tocumen abutted. Apart from man-made barriers, the somewhat heavily vegetated and rough terrain in certain locations surrounding the mega mall would likely deter pedestrians from making the walk (Figure 4.29 a – h). Outside of the possibility of pedestrians needing to cross the mall's premises to arrive at the future metro station, it is assumed that residents in 24 de Diciembre may desire to visit the mall or other attractions on the Nuevo Tocumen side. This was clearly the case. As can be seen in Figure 4.30, residents of 24 de Diciembre cross into the mall's premises through a hole in the fence. Small dirt desire lines lead from the end of dead-end streets directly to the hole in the fence,

which leads to the conclusion that it is often used. There were also physical signs of a previous hole in the fence, which has been tied up and closed (Figure 4.30c).

Figure 4.29: Barriers to connectivity in Nuevo Tocumen and 24 de Diciembre





Figure 4.30: Evidence of residents adapting to poor connectivity cause by the Megamall in Nuevo Tocumen



As discussed earlier, there are practically zero formal connections between neighborhoods. Of course, this was intensified by the megamall, but natural barriers exist that neither the government nor developers have attempted to redefine. While there are attempts from those living in 24 de Diciembre to access the megamall, no other obvious connections were made between neighborhoods. In some cases, access to the other neighborhood could benefit residents. For example, a prominent bus station (Parada MultiCarnes) with multiple bus lines is located in the neighborhood just south of 24 de Diciembre (Figure 4.31a). This is within walking distance for residents in the southwest corner of Nuevo Tocumen; however, the river widens, the elevation decreases and the vegetation is quite heavy (Figure 4.31b). It would be difficult for pedestrians to cross with any sort of ease. Other than large natural barriers, blockades and dead-ends commonly separate neighborhoods from one another (Figure 4.31e-f). Even within formal neighborhoods, impasses exist. While rivers, trees and rough terrain have been flattened or covered in the formally constructed neighborhoods, in 24 de Diciembre, these natural barriers have greatly impeded street connectivity.

As discussed in the literature review, subdivision controls in Panama demand that developers leave a three meter wide easement when the distance between two intersections of a block is longer than 180 meters. In Nuevo Tocumen, there was only one block with a distance between intersections longer than 180 meters. Fortunately, the law was enforced and an easement was placed directly in the middle of the block (Figure 4.31g). However, it is unlikely that passersby would identify it as public right-of-way. Nonetheless, it does exist and allows for greater permeability in the area. This rule does not apply to undeveloped blocks.

Figure 4.31: Large bus stop (a); Disconnectivity between neighborhoods (c-f); pedestrian right-of-way (g)



There are approximately 6.18 km of considerably wide rivers running throughout 24 de Diciembre with only 15 known bridges crossing (Figure 4.32a-c). While these rivers likely play an important role in the life of the residents, their presence no doubt impedes upon the overall connectivity in the neighborhoods. Since the on-site visit was quite limited, it is assumed that other, self-made bridges or paths exist where residents can cross the rivers.

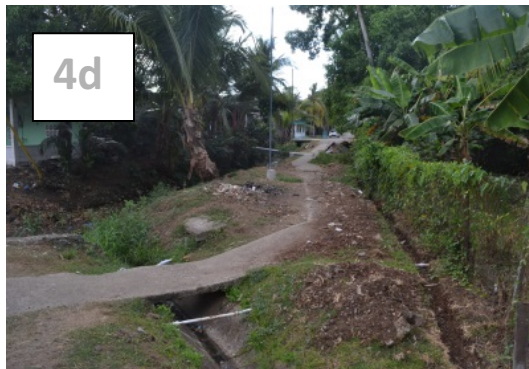
From the spatial analysis of the five representative neighborhoods, it was apparent that the street network in Panama, especially in the areas not centrally located, do not support a pedestrian- and transit-oriented mobility system. For the most part, the on-site visit of 24 de Diciembre and Nuevo Tocumen reinforced this conclusion. However, as the broken through fence at the megamall can attest, residents of Nuevo Tocumen and 24 de Diciembre have ostensibly adapted to the disconnectivity in a few cases. Informal paths were present in many of the “areas of poor connectivity” and likely represent important connections that save residents a great deal of time (Figure 4.32d-f). It can be assumed that this is the same story throughout the entire metropolitan area. Yet, even with these make-shift improvements, poor connectivity and lack of pedestrian infrastructure gives the impression that planning for the pedestrian is not a priority for developers or government officials. This is especially alarming given the large portion of residents in the area that depend on their feet and public transit for mobility.

While the findings from the on-site visit were somewhat distressing, there is ample opportunity for corrective actions to be taken that could create a more cohesive and well-connected street network suitable for pedestrians. Firstly, Nuevo Tocumen has a consistently well connected street network with small blocks. Secondly, thanks to the organic development of 24 de Diciembre, the neighborhood is lush with vegetation, which provides abundant shade. While not necessarily associated with the street network, it is key to a pedestrian-oriented environment in tropical climates. That being said, the formally built neighborhoods lack any sort of vegetation. Thirdly, spaces between neighborhoods as well as the areas along the rivers in 24 de Diciembre, offer opportunities to increase street network connectivity in a way that supports a pedestrian- and transit- oriented mobility system. A few patches of land that were believed to be empty, according to satellite imagery, are quickly being settled upon (Figure 4.32g-i) between neighborhoods,

which will make corrective action more difficult and less flexible than it has already become. In one case (Figure 4.32i) a cement road had already been built in an ad hoc manner. From the spatial analysis and the on-site visit, sufficient information on the current street network growth patterns has been gathered to offer recommendations.

In the following section recommendations are presented in two parts: corrective and preventative. The corrective measures are meant to guide neighborhoods and leaders in the community on how to correct for poor connectivity throughout the metropolitan area. These will be based on illustrations of Nuevo Tocumen and 24 de Diciembre. Preventative recommendations seek to influence the regulatory environment that governs the construction of the street network. These recommendations are in the form of policies and guidelines that city officials and developers can use to ensure a greater degree of connectivity throughout the growing city.

Figure 4.32: Rivers in 24 de Diciembre (a-c); Locals adapting to poor connectivity (d-f); New informal settlement growth (g-i)



Chapter 5: Policy Recommendations

Numerous factors are responsible for creating a pedestrian- and transit- oriented city, one of these factors being street network design. Streets are the most permanent urban feature; once laid they are unlikely to change for decades or even centuries. It is critical that flexible street networks be formulated and planned correctly from the beginning to avoid costly corrective measure in the future. Not only this, but the street network sets the groundwork for the way the physical and social environment are arranged. Since the emergence of the private automobile, the way city streets are organized has been radically altered.

In Panama, as with many cities in the world, street blocks have been getting bigger, and the overall connectivity of the network has been decreasing. This is the result of planning for the automobile and a lax regulatory framework that offers little guidance on issues such as street connectivity for new developments. Therefore, corrective action must be taken to increase connectivity in the existing urban extent. Furthermore, Panama's population is expected to grow by 1 million people by 2050. This means that unless preventative action is taken, future growth will reflect the current patterns of development, resulting in an urban extent that is automobile-oriented, fragmented and poorly connected.

The following section outlines corrective and preventative recommendations that were informed by the analysis in Chapter 3. These recommendations come in the form of suggested new policies as well as changes to the existing policies that govern the construction and management of the metropolitan area's street network. The purpose of each policy is meant to direct the street network in a way that it becomes supportive of a pedestrian- and transit oriented mobility system. With the arrival of a metropolitan-wide, fixed-rail system, it makes sense to first direct corrective action towards the areas surrounding fixed-rail transit station sites. Urban growth is a continuous process and efforts to plan for growth should also be prioritized. While preventative and corrective actions can be somewhat disparate goals, single policies can increase connectivity in the existing urban extent while making

provisions for future growth. For example, expanding the arterial street network can improve connectivity in existing neighborhoods by connecting dead-ends, while directing population growth in appropriate areas.

5.1 Corrective Policies

The corrective policies here are based on the issues brought forward in the analysis. Ultimately, poor connectivity and a severe absence of arterial roads are the fundamental problems that keep the AMP's street network from supporting a pedestrian- and transit-oriented mobility system. While adhering to standards will be important to achieving a more pedestrian- and transit-oriented mobility system, corrective efforts are heavily based on the local context. If the city takes on the challenge of improving connectivity it should be directed by a planner who has a critical eye and is fully aware and informed of the benefits of connectivity. When resources are being invested to achieve greater connectivity in existing neighborhoods, it is important that those connections are made where needed. In other words, connections should not be made just for the sake of connections.

1. The space between disconnected neighborhoods should be taken advantage of to increase connectivity. In Panama it is very common for subdivisions to lack any form of connections to surrounding neighborhoods, both formal and informal. This was seen clearly in the harsh divide between 24 de Diciembre and Nuevo Tocumen. The gap of undeveloped land between the two neighborhoods is as wide as 215 meters at some points, with the narrowest point approximately 25 meters. Currently, around 55 cul-de-sacs or dead-ends touch this undeveloped gap of land making it an excellent opportunity to improve connectivity. In addition, an arterial street can continue to act as a border between the two neighborhoods. As can be seen from Figure R1, this arterial road can then be extended and lead to future development.

2. River should be regarded as special areas of opportunity to increase connectivity (i.e. linear parks, bridges, pedestrian paths, cover and pave, etc.). Similar to the Corrective Policy 1, this policy aims to take advantage of an unused space that can improve connectivity. As was seen in the analysis, dead-ends abut the rivers, thus seriously hampering connectivity. Rivers offer a

unique opportunity to improve connectivity. It is important to understand what benefits locals derive from the river before implementing any sort of change. In any case, with thoughtful and creative design efforts as well as community input, the banks of rivers can be manipulated to facilitated pedestrian or bicycle movement while continuing to offer whatever benefits local resident might currently receive from the natural feature.

3. The Pedestrian Directness ratio should be calculated for all properties within walking distance of a future metro station site and corrective action should be taken to lower areas with high ratios. Transit authorities must decide on a desired maximum ratio, but according to the analysis, a ratio of 1 to 1.3 is desirable and any area with a higher ratio should be avoided. This could simply be accomplished by implementing Policies 1 or 2, but these are not always viable options. Therefore, once an area with a high pedestrian-directness ratio is identified, city planners can work with business owners and residents to find solutions and increase the route directness. This could be accomplished in any number of ways. In the case of Nuevo Tocumen, removing the fence surrounding the megamall and providing adequate pedestrian paths could be sufficient. In Figure R1, the extension of a new arterial would give the residents in 24 de Diciembre a quick route to the future metro station without having to cut through a private commercial property.

4. Neighborhoods should each have a link-to-node ratio of 1.4 or higher. This can be accomplished through achieving policies 1 and 2; otherwise, wherever poor connectivity is identified, connections should be made, if feasible and with as little disruption to private property as possible. UN-Habitat (2013) state that a link-to-node ratio of 1.4 is a minimum requirement for a walkable community. When calculating the link-to-node ratio for existing neighborhoods, all intersections, dead-ends and cul-de-sacs should be regarded as nodes. The only exception to this are dead-ends at the edge of a neighborhood that leave open the possibility for future extension or connection.

5. Large blocks with large buildings must provide through paths for pedestrians. Barriers such as walls and fences, that hinder pedestrian flow, should be removed. This is especially important in areas that are within the 800 m radius of a metro station.

If large buildings exceed maximum block lengths (established in the preventative policy section), then barriers should be removed and paths provided.

6. Informal connections built by locals should be studied and reinforced or improved structurally if proven valuable. It is assumed that locals know their neighborhoods much better than any outside planners or city officials. Therefore, a good starting point would be to look at how locals have adapted to poor connectivity. Not only are self-constructed connections important, but they lead to a better understanding of the problem that forced the locals to make the connections in the first place.

5.2 Preventative policies

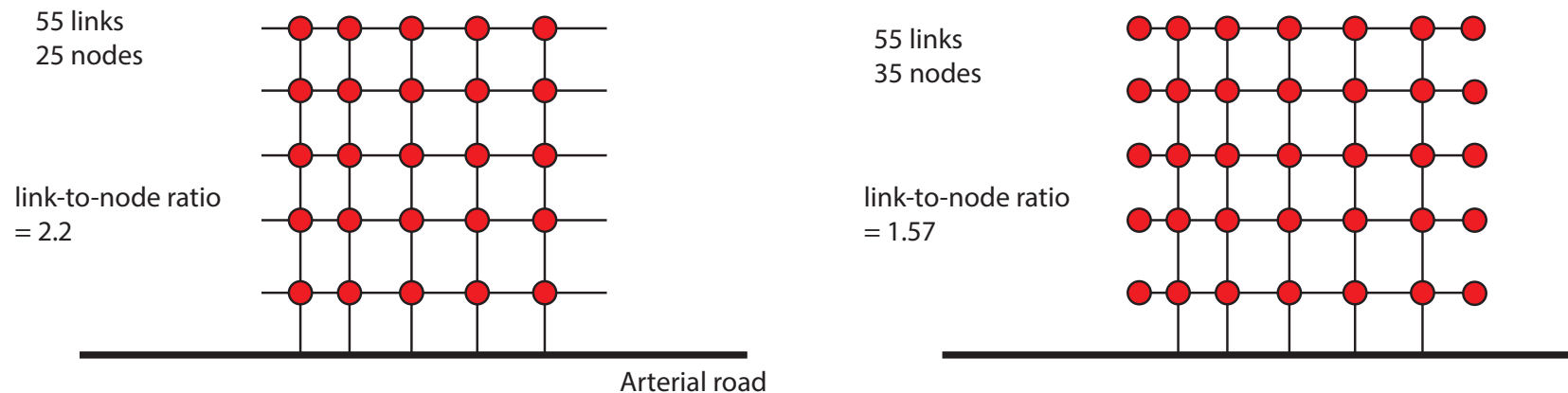
Preventative policies are more reliant on standardized criteria such as maximum link-to-node ratio, traffic sheds, and block and cul-de-sac length restrictions. While corrective policies require intensive planning and community participation, preventative policies are meant to lead future growth and ensure connectivity from the beginning of development, which mitigates the need for corrective action in the future.

1. The creation and legalization of a city-wide arterial street network plan should be implemented to direct future growth in an organized and coherent manner. It is recommended that arterial street right-of-ways have a minimum width of 30 meters and are spaced at 1km intervals so that every address is within walking distance of an arterial road. In Panama, a homogenous grid that expands through the city is not feasible. Due to growth patterns and geographic barriers, the city's future growth can be arranged in packets that have diverse orientations. The National Subdivision Law in Panama states that when a development crosses or is affected by an arterial road the easement or right-of-way will be marked in the Official Street Network Plan. It also states that an arterial road should have a minimum easement of 20 meters wide. However, as mentioned previously, no official plan actually exists. An official plan must be formulated and required by law to go into effect as soon as possible. Minimum easements should be increased to a

minimum of 30 meters to included space for four lanes of traffic, dedicated transit lanes, parking and adequate space for pedestrians and cyclists.

2. New subdivisions should strive to achieve an internal street link-to-node ratio of 1.5 or higher. Due to the flexibility that this ratio provides, developers can take into account topographical variations. By requiring developers to achieve a minimum link-to-node ratio it will help to discourage the construction of cul-de-sacs. When a subdivision is built it will be important to leave dead-end stubs open for future connections. Therefore, in Panama, the link-to-node ratio should only be calculated for node that represents three or four-way intersections and cul-de-sacs that do not have the potential for future connections. In figure R2, it is clear that whether or not dead-ends are considered can seriously affect the link-to-node ratio. In Panama, dead-end stubs that leave room for future connections are extremely valuable, so no regulations should discourage this.

Figure 5.1: Figure depicting the link-to-node ratio when including dead-ends or not



3. Intersections of any subdivision within an 800m radius of a fixed-rail transit station should aim to achieve a pedestrian route directness ratio of 1.3 or lower. A perfect rectilinear grid offers a pedestrian route directness ratio of 1.27 within an 800-meter radius of a location. While other street network designs have better results such as a pure radial network, it is unlikely that most subdivision will be able to employ such designs.

4. Any residential development should provide access points to and from the neighborhood in four directions, most preferably towards an arterial road or a provisioned arterial right-of-way. This approach was implemented in Fort Collins, CO and is referred to as a ‘traffic shed’ approach because it sheds traffic to different directions. Currently, greenfield developments are required to provide no more than one access road from their development. The optimal scenario would be that each connection leads towards an arterial road, but today in Panama, as stated, there is a severe lack of arterial roads so it would be difficult in certain locations to provide these connections. However, once an official plan is drawn up, developers will be able to orientate their subdivisions towards future arterial roads. In the meantime, by providing access roads in at least four directions, residents will have more options giving them quicker access to other neighborhoods, commercial centers and public amenities.

5. New subdivisions built along the border of an existing subdivision must connect new streets to existing dead-end stubs. This policy is critical to increasing connectivity in the metropolitan area of Panama. This will avoid the current pattern of development where developers avoid any sort of connection to surrounding neighborhoods.

6. Any subdivision that borders an arterial road or a provisioned arterial road right-of-way should provide local street connections spaced no more or less than 100 to 180 meters between intersections. This policy will help to ensure that areas closest to arterial roads are porous. This is important since public transit routes will likely run along arterial streets. This policy, along with the “traffic shed” policy, ensures that subdivisions that are not located along arterial roads will be able to find relatively direct routes to an arterial road.

7. Current block length maximums should be reduced from 350 meters to 180 meters. And if a block exceeds 100 meters, a pedestrian right-of-way should be provided at the block's mid-point for all development types. Currently, 350 meter blocks are allowed in residential neighborhoods. However, for industrial and commercial purposes, the length of the block can vary depending on the functional needs of the business. While residential street blocks should be smaller than 180 meters, the required pedestrian path for blocks longer than 100 meters guarantees that a pedestrian will never have to walk further than 90 meters before being able to make a turn. Furthermore, this policy recommendation goes further and requires commercial zones to also abide by the same rules. This would guarantee blocks along the arterial roads would not impede connectivity.

8. Pedestrian paths that cut through blocks or through private developments should be visibly marked and well-maintained for passersby. Visibly marked and well maintained pedestrian paths should be approved by a planner with a critical eye to the needs of pedestrians. This policy would encourage ingenuity on behalf of the private industrial, commercial and residential developers. It could be as simple as an open door policy that directs pedestrians through a mall or an industrial center. The current megamall in Nuevo Tocumen could easily have accommodated pedestrians inside or outside of the actual building. An example of this sort of interaction and cooperation between the public and private uses is Albrook Mall, which is connected to the city's largest bus terminal and the Albrook metro station. The mall becomes a porous activity center that acts not only as a place or destination, but also as a space of flows.

9. Cul-de-sacs should be avoided; however, if inevitable, the length of the road leading to the cul-de-sac should not exceed 60 meters. It is important to note that cul-de-sacs and dead-ends should be identified separately. In this report a dead-end is the end of a street where there is possibility of a future extension. A cul-de-sac are dead-ends where an extension would only be possible if a building was demolished. This policy will be important for a planner to go over plans with developers to make sure that proposed cul-de-sacs are unavoidable.

10. When dead-ends are constructed with the anticipation of future development, a sign should be erected at the stub to indicate the possibility of future connections. If a home-buyer is informed when purchasing the home that a future connection is likely to occur, when that connection is realized there is a smaller likelihood of backlash from the residents.

The purpose of these policy recommendations is to direct the street network in a way so that it supports a pedestrian- and transit-oriented mobility system. The two objectives used to achieve this goal are improving connectivity and expanding the arterial road network. The policy recommendations focus on these two objectives, but are divided into corrective and preventative policies since both require different approaches. Of course, exceptions will have to be made for developers. In these cases, again, it is very important to have a trained planner with a critical eye to review plans. Implementing these policies is an important first step if Panama City truly wants to become a pedestrian- and transit-oriented city. As was presented in the analysis, the effectiveness of a metro system in reducing automobile dependence is strengthened when pedestrian accessibility is improved. And pedestrian accessibility is largely dependent on the street network design. The next chapter presents the final conclusion of the research as well as the limitations confronted and needed future research.

Chapter 6: Conclusion

The beginning of this report stated that there is a persistent concern about mobility in the Panama City Metropolitan Area. While numerous factors are responsible for poor mobility, the structure of the street network rests at the center of the problem. The street network sets the stage for how cities grow, how residents interact with each other, and how they interact with the built environment. As is clear from the spatial analysis, two aspects of the street network pose serious problems for a pedestrian- and transit-oriented mobility system in Panama. First, there is a severe lack of arterial roads. Only about 38% of the urban extent in Panama City is within walking distance of an arterial road. This means there are fewer options for intra-city travel for both private vehicles and public transit routes. This report recommends that an official arterial street network plan be established and enforced. It would guarantee that the city grows in a coherent and ordered manner, instead of illogical and chaotic growth led by private developers. The report also suggests that the space between disconnected neighborhoods be explored as a way to improve connectivity and expand the arterial street network in the existing urban extent.

Secondly, the street network, as a whole, is characterized by poor connectivity. However, the degree and type of disconnectivity is not equal throughout the AMP. Informal settlements, such as 24 de Diciembre, have poor internal street connectivity because settlers lacked the means to break down barriers such as rivers and rough terrain. This resulted in informal street networks characterized by dead-ends and large blocks. On the other hand, formally planned neighborhoods, such as Nuevo Tocumen, display a high degree of internal connectivity, but are often planned with few external connections. Furthermore, laws regulating the construction of subdivisions do not require new neighborhoods to make connections with the existing street network of abutting neighborhoods. Therefore, for a resident of one neighborhood to access an adjacent neighborhood, they must first enter onto the closest arterial road. Recommendations were made that would require developers to abide by block length maximums and connectivity indexes, guaranteeing a highly connected street network.

The limitations of this report overlap strongly with areas of needed future research. As previously stated, there are numerous factors responsible for creating a pedestrian- and transit-oriented mobility system. Aspects such as density and land-use are vital to achieving a walkable environment, but a well-connected street network is a prerequisite to a walkable environment. Therefore, it would not be productive to discuss other aspects of a walkable environment before discussing the basic structure of the street network. That being said, this research would benefit from linking population and demographic variables with the physical street network. For example, it is clear that, in terms of land area, the provision of arterial streets is inadequate. However, it would be even more valuable to understand the proportion of the population that is within walking distance of an arterial road. Furthermore, questions can and should be asked regarding the effects the street network has on social and economic inequalities.

Panama is a rapidly growing metropolitan area, both in terms of population and wealth. If no action is taken, the current pattern of development will continue. While multiple residential housing developments are taking place, one stands out: Porta Norte. This new luxury community claims to be inspired by Casco Antiguo and has been designed as a New Urbanist community with guidance from Duany Plater-Zyberk. It is the first of its kind in Panama and is approximately 11 km². Construction is underway along Corredor Norte, Panama's newest expressway, in the northeastern area of Panama (Figure 6.1). The developers (Grupo Colonias, 2017) claim, "Our mission is to bring back the community that existed in cities before the widespread adoption of the car, recreating the strong ties that existed in communities." The closest metro station will be nearly 3km south of the development and the principal access point to or from the neighborhood is currently Corredor Norte, which is only accessible by vehicles. When the master plan is superimposed on Google Earth, it appears that construction surrounding the development is taking place. How Porta Norte will interact with those neighborhoods is unclear. Nonetheless, the master plan has provided a street layout, which is sufficient to perform a spatial analysis. The same spatial analysis used to evaluate the five representative neighborhoods can be applied to Porta Norte.

Figure 6.1: Location of Porta Norte



Figure 6.2: Porta Norte Master Plan



Source: Grupo Colonius (2017)

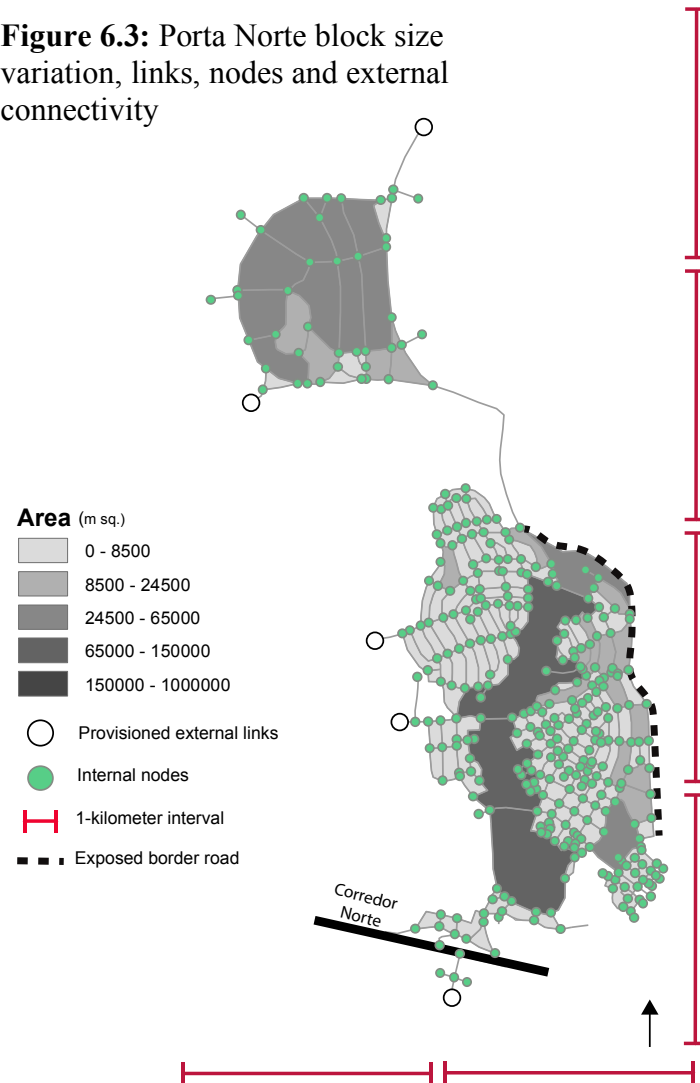
The spatial analysis which was used to evaluate the five representative neighborhoods can be applied to Porta Norte. However, a few obstacles exist that limit the analysis to only a partial comparison. First, there are no arterial roads abutting the Porta Norte development. Second, there are no plans to extend the fixed-rail metro system to Porta Norte so calculating the catchment area for a hypothetical metro station is arbitrary. Link-to-node ratio, average block area and perimeter, and the degree of external connectivity are analyzed and presented in the following paragraphs. The master plan (Figure 6.2) was converted into a street network shapefile. While detailed information regarding the street network was not available, all pedestrian paths, alleyways, and plazas were included as streets since pedestrians can use them. Vehicle streets (white streets) alone would render Porta Norte a very unfriendly pedestrian neighborhood, but the abundance of pedestrian paths creates the foundation for a more porous and walkable environment.

The most alarming aspect of the master plan is the lack of proposed external connections. As stated, there are no arterial roads in the vicinity of Porta Norte, but there are five roads that appear to be provisioned to extend externally. Likewise, there is a street that borders the east side of the neighborhoods that could likely serve as a connector to other neighborhoods (Figure 6.3). As was determined in the spatial analysis in Chapter 4, formal neighborhoods tend to have a better degree of internal connectivity. This is true for Porta Norte as well. Street connectivity is at the foundation of New Urbanist communities so this is not surprising. There were 481 links and 353 nodes identified. Nodes that served as future extension to other neighborhoods were excluded from the calculation. This results in a link-to-node ratio of 1.36. While this is not extremely high, it does, at least, exhibit a baseline link-to-node ratio for a walkable environment.

As is illustrated in Figure 6.3 below, Porta Norte is, for the most part, composed of small blocks. The average surface areas of all blocks is 8,059 m², which is between the average block sizes found in Colón (6,191 m²) and La Exposición (10,611 m²). The average surface area of blocks in Casco Antiguo is nearly half the size at 4,930 m² (Figure 4.16). The average block area is much lower (6,586 m²) if the large blocks in the center portion of Porta Norte are not included. To be fair, the large blocks in the center

portion are due to a river and it is unclear how pedestrian will interact with it based off the master plan. However, no crossing paths are marked beside the five street bridges.

Figure 6.3: Porta Norte block size variation, links, nodes and external connectivity



The New Urbanist community of Porta Norte exhibits many of the necessary aspects of a pedestrian- and transit-oriented street network. The neighborhood is composed of small blocks and cul-de-sacs are nearly inexistent. It also has an acceptable link-to-node ratio; however, it is rather insular and the possibility for street extensions to future surrounding neighborhoods is poor. So, while future residents of Porta Norte may enjoy a walkable environment in their own neighborhood, the rest of the city is only accessible by motorized vehicles. Furthermore, since no arterial roads have been provisioned, the entire community will be forced to access the city via expressway. This is quite extreme since the neighborhood extends over 3 km north from the expressway.

The lack of external connectivity and auto-dependency of Porta Norte, a New Urbanist community, is a testament to the fact that unless regulations regarding connectivity are implemented and enforced by the government, a pedestrian- and transit- oriented street network will not be achieved by the private sector. In order to adapt the AMP's street network to one which supports a pedestrian- and transit-oriented mobility system, the government must take an active role. This report has laid out policy recommendations that prioritize pedestrians and, if followed, will lead to an overall more connected and flexible street network. While corrective measures will be costly in the coming years, preventative policies will mitigate the need for corrective action. A well-connected street network, with adequate arterial roads is just the first step, but it is vital if Panama City is to achieve a pedestrian- and transit-oriented mobility system.

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