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Anatomy of an Informal Transit City: Mobility Analysis of the Metropolitan Area of Lima

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Abstract: Lima, as the capital of Peru, has become its first megacity with more than 10 million people in an area that extends over 80 km in a North-South direction. As a city of this size, it faces complex mobility issues with a strong reliance on informal transport modes (buses, minibuses, and paratransit vehicles) due to the deterioration of its transit system quality during the 20th century. This paper examines the current urban situation in Lima through an analysis of the city's structure, with an emphasis on its transport history and the resulting types of walking, transit, and car-oriented fabrics that can be identified. The mobility analysis was made through data collection, including daily trips by public and private modes, annual passenger kilometers and vehicle kilometers of travel, length of exclusive lanes for public transport and freeways, car and paratransit modes ownership, transport emissions, and safety. These data are used to position Lima in a comparative global context showing its relative strengths and weaknesses in urban form and mobility and providing suggestions for a more sustainable transport and land use system. It is asserted that Lima is an informal transit-oriented city, as distinct from recognized transit metropolises (e.g., Tokyo or German cities such as Berlin or Munich), which often involve private companies, operating under an umbrella of strong government regulation, fare setting, and high service standards. Lima is shown to have some important qualities such as a high density, comparatively low car ownership and freeway provision and still healthy levels of transit and non-motorized mode use despite non-ideal conditions for either. These qualities, if combined with effective governance structures, government commitment to higher quality formal transit systems, which better integrate the important informal transit sector, cessation of high capacity road building, greater protection and encouragement for non-motorized modes and some effective controls over growing car and motorcycle ownership, would see Lima develop a more sustainable transport system.

Keywords: Peru; Lima; Latin American cities; urban mobility; urban fabrics; informal transit; paratransit; walking; transit and auto cities

1. Introduction

The city of Lima is the capital of the Republic of Peru, a Latin American emerging economy. The history of the *City of Kings* traces back to Pre-Hispanic times but it was officially founded by Spanish colonizers as the capital of the Viceroyalty of Peru in 1535. Since then, it has become the political, economic, and cultural center of Peru and a reference for the rest of the cities in Peru. Today, Lima has a population of 10.3 million inhabitants [1], which makes it Peru's first megacity. Its growth has conformed to the migration processes from rural areas throughout the 20th century, which today make Lima a multicultural city with people of diverse ethnic background from all over the country [2].

Its history is marked by encounters between formal and informal structures, urban expansion processes, and the clash between different social strata. This duality and mutual influence of formality and informality [3] is reflected in the mobility situation of Lima, with informal transit modes, which arrived in the early years of the public transit era. During the 20th century, the transport system quality deteriorated greatly, especially transit, which nevertheless remained crucial for its citizens' economic well-being. Today, there are still countless users of these informal modes, along or in combination with formal mass transit that arrived in the 21st century.

Throughout the paper, the American abbreviated term "transit" will be used, when referring to public transport. However, "informal transit" requires further elaboration as it does not imply something necessarily inferior, since most informal transit systems exist to fill a critical gap in the supply of mobility services due to the failure, for whatever reasons, of government to provide traditional formal transit, be that buses, rail, or ferry modes. In this sense, they often fill an indispensable role in the transport systems of low income cities, providing low cost mobility to millions of people who would otherwise be without viable transit options. For this article, the term "informal transit" follows the definition from Robert Cervero in his paper entitled *Informal Transport in the Developing World* [4], in which he explains it as low-performance vehicles of low capacity that are driven by private operators often without official permits, registration, proper credentials or other certifications regarding the vehicle and insurance. Informal transit often serves as feeder connections between mass-transit and peripheral low-income, non-formal urban settlements without proper road infrastructure, where no other transit modes can reach. Informal transit also offers wider coverage with high frequencies that allow short waiting periods and shorter walking distances to bus stops [5].

It is important to note that the involvement of private operators in transit systems does not singularly imply "informality" of transit services, since countless cities in the world have contracted private operators to provide mainstream, conventional transit services under the umbrella of formally regulated governance systems [6]. However, informal transit is privately provided through concessions to transport companies and may be offered through less legally stable licenses and sometimes linked to corruption cases [7]. Public policy expressly permits this situation, which in turn is linked to the way informal transit creates numerous jobs for an unqualified population without a regulatory framework nor action by the State. The State even provides incentives for industrial production of small vehicles made for informal transit and/or importation of the same type of vehicles (new and/or used) from other countries [8]. This lack of formal regulation from authorities within a free market, effectively allowing a form of "self-regulation", has led to an explosion of small capacity vehicles as drivers ruthlessly compete to get more passengers [9]. Transit users end up being the most affected parties, without any ability to control the situation [5].

This paper attempts to explain the current urban situation of Lima as a complex example of a Latin American city and to answer the following questions: (1) What is Lima's current city structure and how has that been shaped over time? (2) What is the transport history of Lima, how has it evolved to its present situation and what kinds of urban fabrics has this produced? (3) How does Lima compare to a sample of other world cities and what strengths, weaknesses and policy lessons does this reveal for now and the future? (4) What might Lima do to strengthen its urban structure and improve its transport system?

This paper is structured around answering these four questions. This is approached first through an analysis of current city structure involving the center(s) and sub-centers of the metropolitan area, the peripheral districts, areas involved within the city dynamics and the segregated sectors. Municipal documentation, metropolitan plans, maps, and publications by specialized authors in the field were reviewed.

Following this, a mobility analysis of Lima is provided, with the history of the transit modes that have appeared and disappeared, including the arrival of the automobile and current paratransit/informal transit modes. This investigation also identifies and distinguishes the different types of urban fabrics in the metropolitan area: walking, transit and car-oriented areas. These fabrics are important in understanding how Lima might evolve into a stronger transit model based around its extensive,

dense land use patterns. Some of these pre-date the car and others belong to dense peripheral and originally non-formal settlements that can be ideally suited to sustainable transport modes and which are physically unable to accommodate high levels of car use.

The comparative mobility analysis of Lima covers the number of daily trips by transit and private transport, annual passenger kilometers and vehicle kilometers of travel, length of exclusive lanes for transit, freeways, car and paratransit modes ownership, transport emissions, and safety. Surveys from international agencies, governmental reports and statistics, as well as evaluations carried out by urban observatories were examined. From these numbers, comparisons were made with the situation of other individual cities and more generally, representative samples of American, Australian, Canadian, European and Asian cities to find where Lima is positioned in a global perspective on key transport-related indicators. This leads to perspectives on Lima's strengths and weaknesses and conclusions about whether Lima is a walking, transit or car-oriented city. These results are used to assess future prospects for Lima and provide recommendations about tasks and priorities required to improve its current situation.

2. What Is Lima's Current City Structure and How Has That Been Shaped Over Time?

Lima is a coastal capital that extends along three valleys formed by the Rímac, Chillón, and Lurín Rivers. Despite being located twelve degrees below the Equator, it does not have a tropical climate. On the contrary, Lima has a desert climate where it only rains on average 6 mm a year. It is characterised by heavy fog and humidity near the coast due to the cold Humboldt current that flows from the south of the continent [10]. Lima is the political, economic, and cultural center of Peru and has become its first megacity with 10.4 million inhabitants and 2.8 million homes, yielding an average household size of 3.7 persons [1]. The city has evolved from a Pre-Hispanic settlement over which the Spanish superimposed an orthogonal grid later surrounded by walls, to a city formed by formal and informal expansion processes beyond the original center between periods of economic growth and political instability. The most significant expansions have been the urbanization of the agricultural land between the center and the traditional Southern upper-class neighborhoods such as San Isidro and Miraflores, and occupation of the periphery of the city with consolidation of the informal settlements or barriadas. These were the product of migration waves throughout the second half of the 20th century, which caused a population explosion in Lima (Figure 1 [11]).

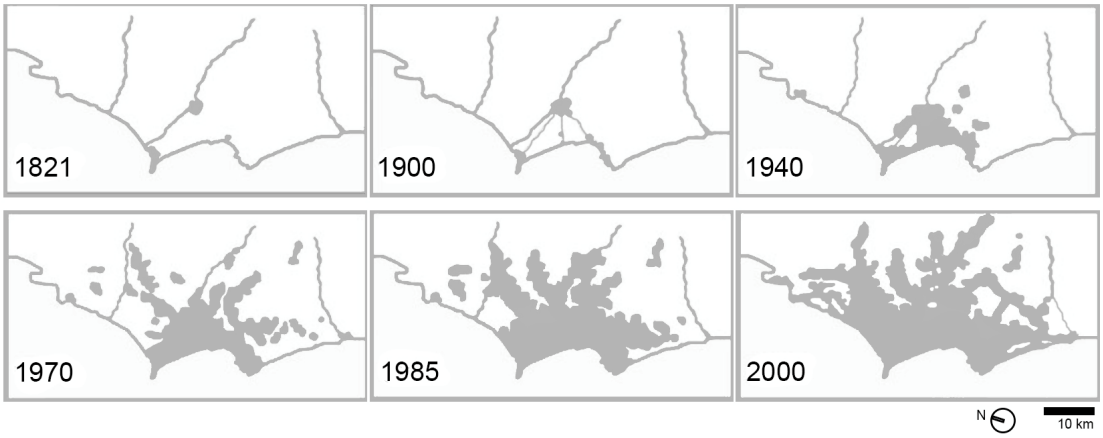

Figure 1. Historical evolution of the city of Lima. Source: Reference [11].

Recent Peruvian urban studies identify three periods of barriadas. The first one occurred between 1940 and 1954 on the closest hillsides that surrounded the city and along the axes that connected Lima with Callao that were still non-urbanized. Their inhabitants depended on the traditional center for the supply of goods and services, and for work as they settled around the industrial areas of that time. Since 1954, the new barriadas settled outside the nearest periphery of the city. The selected occupation

areas were lands with very low value and in most cases owned by the State. These settlements contributed to the fast urban expansion of the city and the population boom. Between the 1950s and 1980s, the city increased from 1 million to 5 million people [12]. Unlike the previous barriadas, these settlements created new attraction nodes in the city for more newcomers, who settled along expansion axes beyond the urban area in Northerly, Southerly, and Easterly directions. The State passively allowed the existence of these settlements, provided they did not occupy valuable land for real estate [12]. The final period started at the end of the 1980s, when migration decreased because the living conditions of these new settlements were not better than in other Peruvian cities, but also because the informal expansion had taken over all the available valuable land. The occupation from this period was in lands far beyond the urbanized area of Lima or in marginal lands around the now consolidated barriadas from the previous period [12].

Today's metropolitan area is an urban agglomeration formed by two autonomous provinces: the Province of Lima and the Constitutional Province of Callao. The first is located inside the region with the same name: The Department of Lima. However, as the capital of Peru, this province does not belong to any region of the country and has a special designation as a municipality, which is vested with the same political, economic, and administrative functions of a regional government [13]. The mayor also has the same powers as a regional governor. Lima Province is also formed by 43 autonomous districts, each one with its own mayor, who has authority on a district level. The second province that forms the metropolitan area is Callao, which is governed by a regional and a provincial government over the same territory. Callao also consists of seven autonomous districts that have their own mayor [13]. Consequently, apart from two administrations for Lima and Callao, there are fifty additional mayors from the autonomous districts of the metropolitan area. Both provinces are autonomous and are primarily concerned with their own interests, without taking in consideration the impact on each other. This disconnected governance represents a huge problem because they also depend on one another in a variety of ways. For example, the international airport and port are in Callao, while Lima is the economic center of Peru [13]. The biggest water plant is in Lima, while the most important waste water treatment plant is in Callao [13]. This special governance structure has a great impact on citizens' lives, especially within the transport sector, as later detailed.

2.1. Four Limas and El Callao

The Province of Lima is divided into four sectors that are complemented by the Province of Callao and the northern and southern summer resorts, known as the balnearios of Lima. To describe these sectors, the socio-economic levels (NSE) standardized by the Peruvian Association of Market Research Enterprises (APEIM) were used in Table 1 [1] to give more information about the population that live in each sector, with A/B referring to upper and middle-class families and E to the lowest-income population. Figure 2 [13] provides a map of the metropolitan region, showing the four Limas plus Callao.

Table 1. Lima's population according to its five sectors and socio-economic levels in 2018.

Zone	Inhabitants		Socio-Economic Level Apeim (Horizonal %)			
	Thousands	% over Metropolitan Lima	AB	C	D	E
Central Lima	2133.5	20.6	57.5	33.1	8.1	1.2
Northern Lima	2581.1	24.9	23.8	48.3	23.5	4.4
Eastern Lima	2553.6	24.6	21.1	43.4	28.9	6.7
Southern Lima	1935.8	18.7	17.2	41.4	31.0	10.5
Callao	1053.0	10.2	25.7	42.9	23.0	8.4
Balnearios	108.3	1.0	11.3	56.6	23.0	9.1
Total Metropolitan Lima	**10,365.3**	**100**	**28.9**	**42.2**	**23.0**	**5.9**

Source: Table by authors from data in Reference [1].

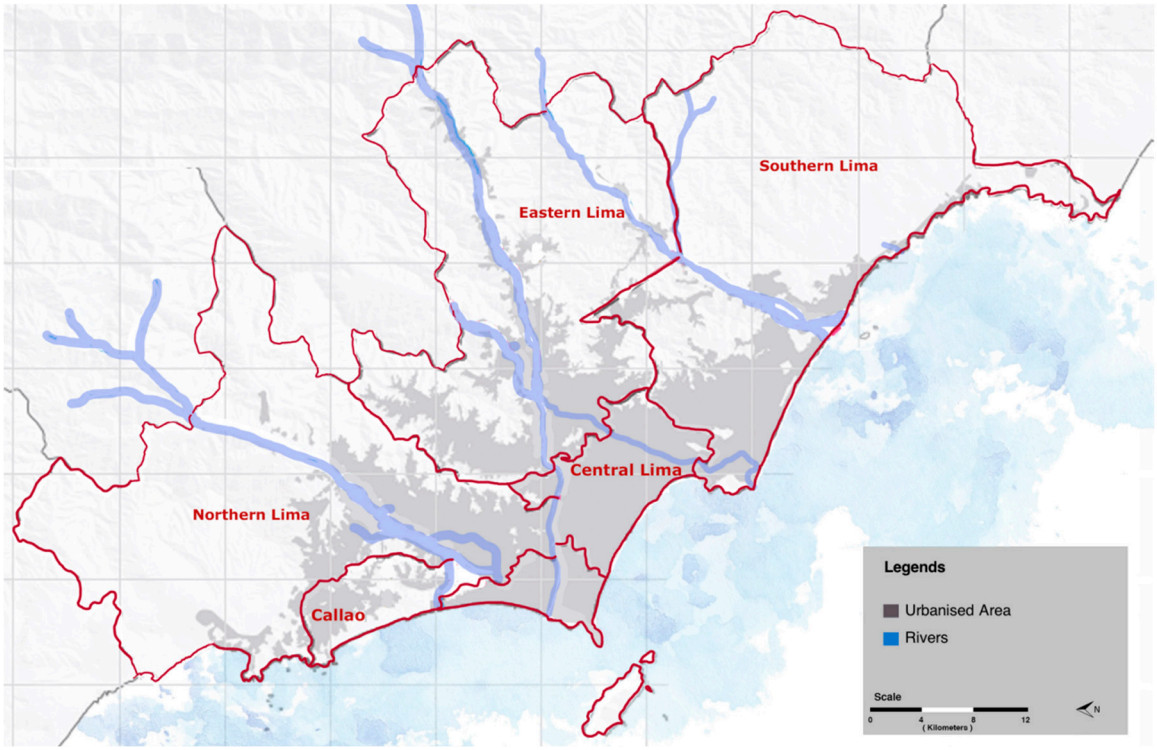

Figure 2. Metropolitan Lima formed by the four *Limas* and Callao. Source: Reference [13]. Map edited by authors.

2.1.1. Central Lima

This covers the first expansions from the colonial city center Southwards over the rural land, commencing after the Independence of Peru up until the 1950s. It is formed by seventeen districts that represent 20.6% of the city's population [1]. While these districts are very diverse in socio-economic levels, they have the most consolidated urban fabrics, share the same identity as a traditionally non-migrant population and earn the highest income in the city. These areas also have the highest concentration of services, public institutions, and jobs.

2.1.2. Lima Conurbana

This area is the result of the now consolidated *barriadas* that appeared with the internal migration waves since the early 1950s. From dormitory settlements, they have turned into places for new economic dynamics of commerce, craft production and manufacturing. Lima Conurbana now houses more than two-thirds of the population of Lima and is geographically categorized into three sectors: Northern, Eastern, and Southern Limas. Northern Lima is formed by six districts and represents 24.9% of inhabitants in Lima [1]. It is known for its entertainment places, especially mass-scale retail centers and educational centres such as institutes and universities along the metropolitan corridor of the Panamericana Norte Freeway. Eastern Lima is formed by seven districts and represents 24.6% of the population, while Southern Lima is formed by six districts and represents 18.7% of the population [1].

2.1.3. Callao

Callao's history traces back to colonial times when it was founded in 1537 as the main port of the Viceroyalty of Peru. It thrived during the 19th century with the building of the railway Lima-Callao and received the name of Constitutional Province in 1857. Notwithstanding this growth, its physical decline began during the 20th century when some of the first barriadas appeared along the axes of Callao-Lima [12]. It is formed by seven districts that represent 10.2% of the total population [1].

2.1.4. The Balnearios

These summer resorts, isolated from the city, were integrated and assimilated by the metropolitan area throughout the latter part of the 20th century with the construction of the Panamericana Freeway between 1930 and 1950 that provided better access to the beaches. The working class saw the opportunity of opening businesses for the vacationers, work in fishing and construction and became a permanent population of these areas [14]. The balnearios were created as private initiatives without planning, due to economic prosperity and real estate speculation. The remainder of available land was rapidly urbanized at the end of the 1990s and by the beginning of the 2000s these extended beyond the limits of Metropolitan Lima [15]. Due to their function as summer resorts, the seven districts that comprise this area (two located at the northern and five at the southern coastline) only represent 1% of the permanent population of Lima [1]. Due to their physical location, these districts are either part of Northern or Southern Lima.

2.2. Polycentric Lima

Lima re-entered the global economy during the 1990s after introducing economic policies in favor of foreign investment, availability of economic and social capital, and improvements in transport and telecommunications [16]. During this decade, former President Alberto Fujimori's dictatorial restructuring of the State promoted drastic macroeconomic policies and large national investments in the mining sector and others. Although these reforms came with a very high social cost, new dynamics of a global city appeared in Lima with the establishment of new economic components such as technology, production, retail, services, and communications, making it a major investment attractor [17]. These new actors have changed the urban structure of a city that used to depend on its historic center and have furthermore created new nodes all over Lima.

2.2.1. The Historic Centre

The original colonial center and its expansion during the 19th century, was the political, economic and cultural center of Lima until the 1970s, when it was affected by the arrival of informal commerce and transport chaos. These changes displaced businesses to the upper-class district of Miraflores between the 1970s and 1980s [16]. The center was renovated during the 1990s to keep some businesses from migrating, and in the following decade other activities such as galleries, restaurants and retail stores were attracted into it. Maintaining its role as a center for the congregation of counter-cultural movements and in recent years, the historic center has also become the setting for civil society movements.

2.2.2. San Isidro Central Business District (CBD)

Economic growth in the areas of investment and international trade produced the expansion of informational activities. Between 1990 and 1997, the financial sector grew six times, while the energy, communications and transport sector grew more than 500 times, numbers related to the diversification and growth of international commerce [16]. The proliferation of informational activities during the 1990s consolidated the development of the CBD of San Isidro, a traditional upper-class residential district isolated from low-income sectors. While the historic center gathered many other economic, governmental, and cultural activities along with the financial activities, the new CBD was specialized in informational activities only, without commercial, industrial, and entertainment functions [16].

2.2.3. Industrial Areas

The dislocation of the traditional industrial corridors after the economic crisis of the 1980s and the economic restructuring of the 1990s allowed the creation of new industrial nodes [18]. Small businesses found production opportunities because of the recently available qualified workforce and low costs for importing machinery. The sector of Gamarra, originally known as a marginal area of Lima, became a node for the gathering of entrepreneurs in the clothing and fabric sector along with sub-contractors, suppliers, and customers. By the end of the 1990s, it represented almost half of the textile business in Lima [16]. Other industrial nodes are in Villa El Salvador (Southern Lima), San Juan de Lurigancho and Ate (Eastern Lima).

2.2.4. Culture and Entertainment

Culture and entertainment activities proliferated during the 1990s between massive international consumption and the demand of local identity, further influenced by the democratization of the media through the importation of low cost communication devices. The offer of cultural activities is diversified by the historic center and Miraflores district, which consolidated as entertainment nodes through the creation of the San Isidro CBD [16]. Barranco, as a traditionally bohemian neighborhood, became a leisure-oriented district in Central Lima while Lima Conurbana developed its own cultural and entertainment centers, especially in Northern Lima.

2.2.5. Commerce and Retail

Since the 1980s, new commercial dynamics appeared in Lima in areas such as Gamarra, La Parada, Mercado Central and Miraflores in Central Lima, but also in peripheral areas such as the wholesale markets of Ciudad de Dios and Caquetá. Economic expansion during the 1990s emphasized this scenario with the importation of products, promotion of massive consumption, and growth of credit card use [16]. New mass-scale malls spread around the city, forming enclaves without connection with the existing urban fabric. On the other hand, ambulatory trade fairs appeared as infrastructure gathered former street informal businesses. Since the end of the 1990s, commercial retail companies saw in Lima Conurbana an opportunity to invest in retail centers and supermarkets. Mega Plaza in Northern Lima opened in 2002 while CC Atocongo in Southern Lima opened in 2006 [17] and the even larger, Mall del Sur, opened in the Southern district of San Juan de Miraflores in 2016.

2.3. Location of Employment

Gonzales and del Pozo [18] have identified that the main locations of employees are first in Lima Cercado (around the historic center and its first expansion) and then in San Isidro CBD and Miraflores. Yet, when employee density is calculated, San Isidro and Miraflores present the largest concentration of employees per block area. The number of employees in San Isidro and Miraflores is more than half the number of people that live there. This jobs concentration is, however, only in specific areas (Figure 3 [18]) such as the CBD area in San Isidro (with 531 employees per ha) and the commercial area of Miraflores. The following two most important metropolitan work centers are also in Central Lima: Gamarra and Mesa Redonda-Central Market, which has 288 employees per hectare [18]. In this way, although Lima has evolved from a monocentric city to a polycentric model, the most consolidated centers (CBD, commercial and commercial-industrial) are not far from one another and concentrate the major density of jobs on a metropolitan level. While new peripheral centers are being developed, job localization is local but not metropolitan [18].

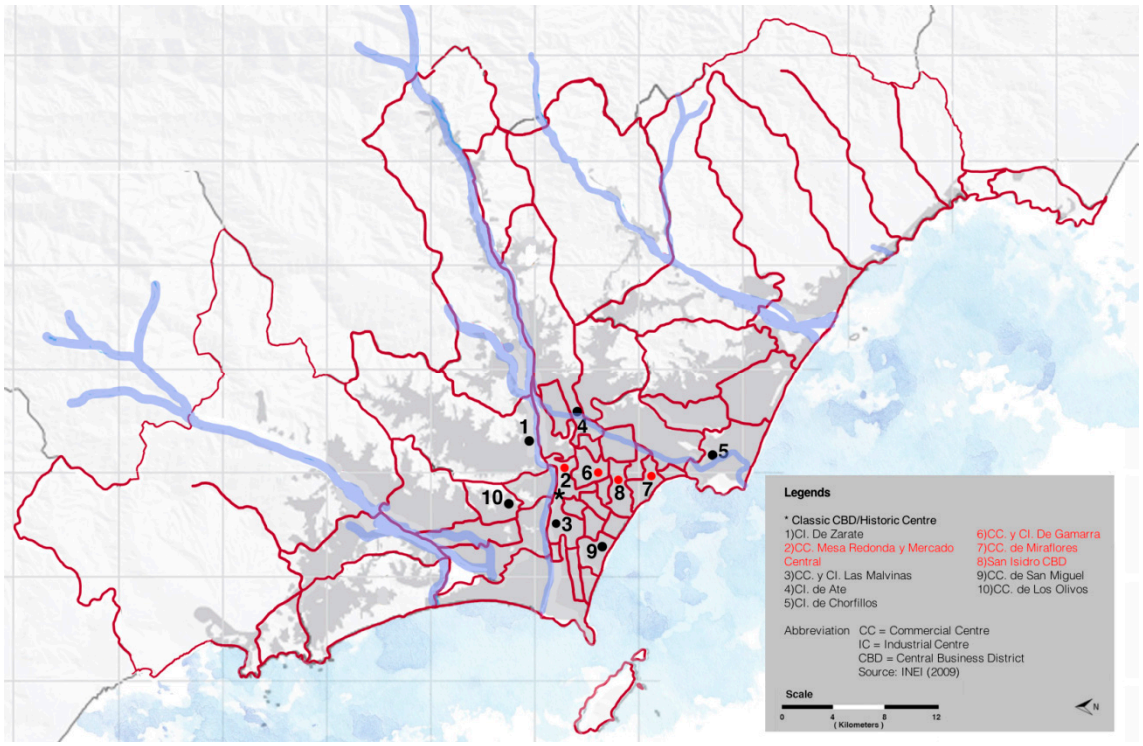

Figure 3. Employment centres in Lima in 2008. Source: Reference [18]. Map translated and edited by authors.

2.4. Segregation Patterns

Since the colonial foundation of Lima, the dominant white European-descended population has mainly dwelt separated from the marginal sectors. When Lima expanded during the 19th century, these sectors penetrated the traditional wealthy areas after the demolition of the colonial walls. As a result, the upper-class migrated from the center Southwards to the districts of Miraflores and San Isidro with village-houses within a controlled urban fabric. Once the middle-class sectors occupied these traditionally rich areas, from the 1950s the wealthy migrated to the Eastern suburban areas such as Monterrico, El Polo and La Molina living on big lots in exclusively residential, low-scale gated communities [19].

Plöger [20], based on the studies of Bähr and Klückmann [21], has identified the following clear patterns for the current distribution of socio-economic levels in Metropolitan Lima:

(1) The corridor of wealth between the central districts of San Isidro and Miraflores and the eastern upper-class/suburban district of La Molina;
(2) The upper-class neighborhoods surrounded by a belt of middle-class residential areas; and
(3) The permanent condition of extremely low-income sectors in the peripheral areas of Lima (Figure 4 [22]).

Today, 42% of the population belongs to the C socio-economic level and 23% to the D level, whereas only 29% is considered part of the A/B level [1]. Poverty in Lima is not only reflected in the percentage that low-income sectors represent, but also in the informal mechanisms of urbanization and the lack of basic services [22].

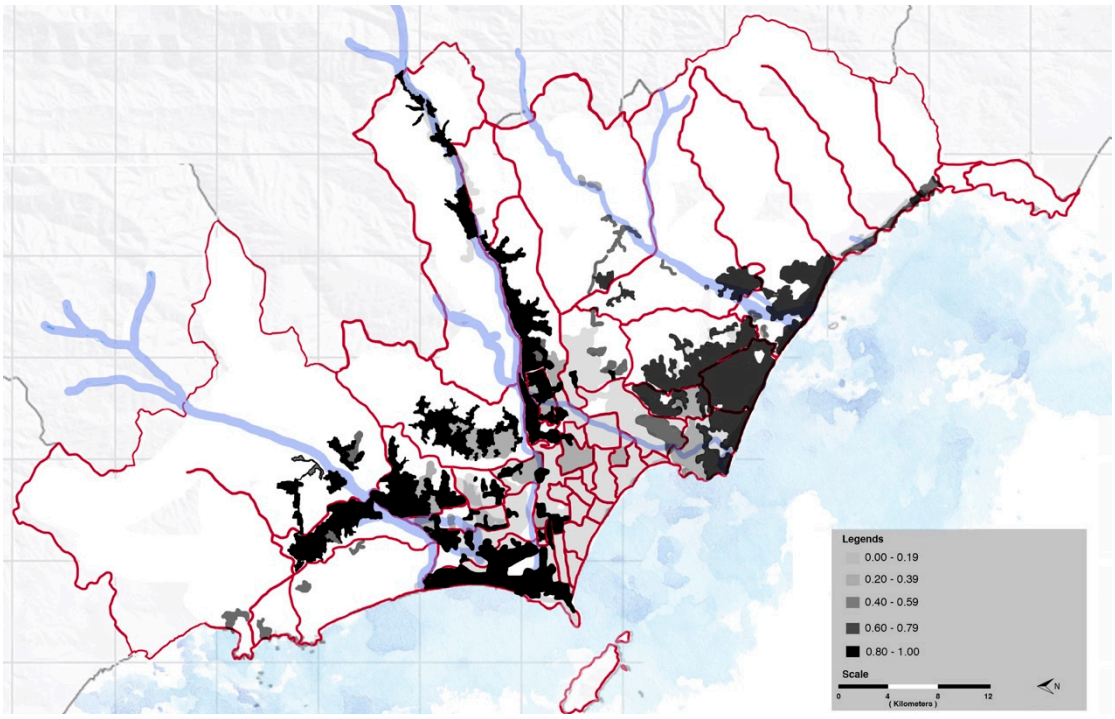

Figure 4. Distribution of low-income population in Lima in 1993. Note: Units are the proportion of low-income population according to the National Institute of Statistics and Informatics (INEI), i.e., low and very low socio-economic levels. Source: Reference [22]. Map edited by authors.

3. What Is the Transport History of Lima, How Has It Evolved to Its Present Situation and What Kinds of Urban Fabrics Has This Produced?

Sections 3 and 4 address the transport history of Lima and the urban fabrics that have been produced.

3.1. The Republic and the Trams

The first horse-drawn tram appeared in Lima in 1878 and travelled around the historic center of the city. The fleet of 20 vehicles was distributed across four lines [23]. The first electric tram operated in 1904 and covered an extension of 26 km between the Centre of Lima and Chorrillos. The system had three urban lines that travelled around the center and three interurban lines that connected the periphery. In total, the railway network was 100 km [13]. Trams were nationalized as the National Tram Company (CNT) in 1934, which owned around 240 tram units [24], but administrative and economic problems of the company generated negative reactions towards trams, while the recently implemented bus services gained more popularity and competed for passengers along the same routes [13]. By 1965, there were only 24 tram vehicles in Lima and in the same year the CNT was finally shutdown with the Anti-Trams Law N° 15786 [25].

3.2. The First Buses and Growing Informality

The first bus service started in 1920. The fleet increased from 160 in 1925 to 400 two years later [24]. The buses had similar routes to the trams from the center to Miraflores, Barranco, and Magdalena. The State controlled the fees and the required characteristics of the bus vehicle. During the 1930s, informal buses appeared in the city to compete with the formal routes. The Metropolitan Company was created as a private initiative to control the buses, but was discouraged due to a lack of governance from the State and new private companies appeared to control the service. Informal transit continued taking over the routes, sending the private formal bus companies bankrupt and giving away the routes to their employees. By 1960, thirty-two of the forty-two formal bus companies were no longer managed by their owners. These also failed to make a profit, so they had to give away their vehicles to their

employees as part of their final settlements. During this decade, there were many bankrupt transit companies administered by cooperatives or workers' companies without organization or professional transit knowledge to ensure optimum service and operation [13].

In 1976, the National Urban Transport Company of Peru (ENATRU) was created to manage transit directly [24] but it still embodied the previous administrative problems [13]. However, the company offered a good quality service with about 600 buses with a capacity (seating and standing) between 80 and 100 passengers [26], which travelled along the reserved lane for a future metro line on the Paseo de la República Freeway. By 1978, informal minibus lines had grown to 117 and covered 83% of the transit demand in Lima, whereas there were only forty formal bus lines that covered 17% of the demand [13]. By 1986, ENATRU only covered 8% of the total demand and in 1990 more than 95% of the bus lines were informal [13] using minibuses with a seating and standing capacity between twenty-five to forty passengers [26]. ENATRU was finally dismantled in 1992.

3.3. Restructuring under Fujimori and the Combis

The hyperinflation at the end of the 1980s left Peru devastated, with no investor interested in transit. Under the presidency of Fujimori, neoliberal free-market restructuring policies served as an immediate response to the high demand for transit with low cost solutions [27]. Legislative Decree 651 in 1991 enacted free access to routes and permitted any natural person to provide transport service with motorized vehicles with more than two wheels without the request for approval from municipalities [28]. Law N° 25789 of 1992 allowed the importation of used vehicles. Minibuses and the so-called combis (units with a capacity of sixteen seated passengers) that had already appeared as informal transit during the previous decades were very important as they involved less investment [27]. These policies without restrictions, along with the high unemployment rate in Peru, led to the overpopulation of routes driven by personnel without any previous knowledge of transit. By the 1990s, Lima had already reached the peak of its metropolitan expansion with the consolidation of Northern, Southern, and Eastern Limas, which still depended on the center. Between 1990 and 2000, these informal units increased from 10,500 to 47,000 [26] transporting passengers from one extreme of the city to the other by always crossing through the center.

This transit privatization resulted in each bus service provider imposing its own transit fare, according to the competition. The system in which these informal lines work is called Guerra del Centavo (Penny War) [24], in which drivers must make more trips per day to compensate for the reduced passenger capacity of minibuses and combis [27]. The legal framework allowed private transit companies to rent their authorization of routes to vehicles owners, who sub-rent their units to informally employed drivers who live on the daily profit. In contrast to formal transit, the fare is extremely cheap, as it is estimated according to travelled distances, so it can vary from 0.31 USD to 1.07 USD [24]. These informal services provided reduced waiting periods (from 5 to 8 min) and allowed passengers to get to their destination without making a transfer. The distances between improvised bus stops were about 500 m [29], perhaps a little longer than typical bus services, which are around 400 m [30].

Overall, this explosive increase of informal bus services resulted in infringement of transit regulations, speed limits and huge competition between drivers to gain as many passengers as possible, often resulting in accidents. While 70% to 80% of atmospheric pollution in Lima is related to transit due significantly to the explosion and bad administration of informal routes [29]. According to the Municipality of Lima, in 2013 there were 13,600 combis, 14,700 minibuses, and 3200 buses with an average age of 22 years [31] and without functioning emissions control technology.

There have been efforts to regulate the lines, starting with Ordinance 104, which sought to regulate bus services through concessions to transit companies for the routes now owned by the Municipality of Lima. However, the ordinance allows companies to sub-rent their fleet [28]. Moreover, corruption cases between municipalities and transit companies have reduced efforts to rationalize bus lines into a more coherent system. The lack of good governance also affects regulation because both Callao and Lima have the authority to register new routes that run across both provinces. In addition, the transit sector

involves around 350,000 people who work in informal transit modes [26], and the income derived from this supports a huge number of households and is therefore difficult to deal with, without causing economic hardship for many people.

3.4. The Metropolitano

During the first municipal government period of Mayor Luis Castañeda Lossio, the implementation of the first and only BRT system in Peru was proposed: El Metropolitano. The project was developed by the Municipality of Lima and received funds from the Inter-American Development Bank and the World Bank. After two terms of Castañeda Lossio as mayor, the system opened in 2010, after almost 20 years without formal transit. The system is implemented along Paseo de la República Freeway's reserved lane for the projected metro line and where the ENATRU buses used to travel and trams before them. The north-south route connects eighteen districts with a reserved lane length of twenty-six kilometers. It has thirty-five bus stops, a central underground station located in Lima Cercado and two transfer terminals. There are twenty-four additional feeder routes connected to the BRT. The reserved lane's buses have a seated plus standing capacity of 160 passengers and are powered by natural gas (Natural Gas Vehicle or NGV) [32]. The final cost of its execution was 300 million USD or double the initial budget, making it the most expensive BRT system in the region (Table 2 [33]).

Table 2. Infrastructure cost per kilometer of different Bus Rapid Transit systems in Latin America. (in million USD).

BRT System	Extension (km)	Year	Main Features	Registered Cost
Curitiba, RIT	65	1973	139 stations, 26 terminals, electronic collection, bike lanes	2.40
Quito, Trolebus	37	1995	68 stations, 9 terminals, central control, electric buses	5.90
Bogotá, Transmilenio	84	2000	High capacity BRT, 104 stations, 10 integration points	8.20
Sao Paulo, Interligado	104	2002	327 stations, 24 terminals, integrated system	3.50
León, SIT Optibus	25	2003	51 stations, central control, 60% segregated	1.80
México, Metrobus Insurgentes	20	2005	34 stations, 2 terminals, central control	2.80
Guayaquil, Metrovía	15.5	2006	36 stations, 2 terminals, centralised control	1.56
Pereira, Megabus	27	2006	38 stations, centralised control	2.89
Santiago, Transantiago	19	2007	70 bus terminals, 2 intermodal stations	4.00
Lima, Metropolitano	**26**	**2009**	**35 stations, 2 terminals, 1 underground station, central control**	**11.94**

Source: Table by authors from data in [33].

3.5. The Metro Line

In 1972, Lima had 3.3 million people and 3 million out of the 4.1 million registered trips were carried out in transit modes. The Technical-Economic Feasibility Study and Preliminary Draft of the Passenger Massive Rapid Transit System in the Metropolitan Area of Lima and Callao proposed the construction of four underground lines of 125 km. The first projected line was from Villa El Salvador (Southern Lima) to Comas (Northern Lima) with an extension of 36.8 km [29]. Due to difficulties in finding financing and technical seismic-resistant challenges, the project was postponed until the first government of President Alan García (1985–1990). During his mandate, the Autonomous Authority of the Special Project for the Mass Rapid Transit Electric System of Lima and Callao (AATE) was created to plan, coordinate, and execute the first line of the electric above-ground mass transit system. García's

economic mismanagement affected the development of the project, which was not completed until his second government (2006–2011) [29].

Line 1 opened in 2011 with an extension of 34 km and changed its final destination to San Juan de Lurigancho (Eastern Lima), but still traversed the same districts in Central Lima to satisfy the demand from the centre [29]. In 35 min, it travels through eleven districts with 26 stations [24]. It has five trains of six carriages with a capacity of 1200 people and 19 trains of five carriages with a capacity of 1003 passengers [34]. The Supreme Decree N° 059-2010-MTC was approved in 2010, supporting a metro network with five lines, three in a North-South direction and two in an East-West direction. In 2013, the Supreme Decree N° 009-2013-MTC added Line 6 to the network [35]. Line 2 is currently under construction with a Line 4 track to connect the current network to the Jorge Chávez International Airport. The total extension is 35 km and will be the first underground metro in Peru, traversing 13 districts with 35 stations that will be interconnected with future metro lines and the Metropolitano [24].

3.6. The Transport Reform

While the Metropolitano and Line 1 of the Metro contributed to reduce trip times in the North-South corridor, these are still disconnected from any other bus network. The rest of the city was still in chaos because of the lack of order of the remaining transit routes. Between 1992 and 2004, the number of transit units multiplied four times while the demand only doubled [29]. Based on this proliferation of low capacity vehicles there is 30% more transit service than is needed to service transit demand, which means more buses travelling along the same routes and competing for passengers [13]. This creates traffic congestion, accidents and greenhouse emissions when mass-transit modes with exclusive lanes could serve the same number of passengers in much better conditions with reduced travelling times.

Efforts during the management of Mayor Susana Villarán contributed to the regularization of transit. Ordinance N° 1538 aimed to limit the number of small informal vehicles in operation, improve traffic flow and reduce pollution. Municipal Decree N° 367 proposed a network of Complementary Corridors through partnerships with private parties. This regulation came with the re-organizing of the main avenues [31] with specific bus stops. Villarán's reform created new conditions for a new transit system: the Integrated System of Transport (SIT) through Ordinance N° 1613. This new system aimed to formalize routes with legally employed drivers and standard rates of pay and integrated with other mass-transit systems in Lima [31]. The SIT proposed the replacement of informal lines with 1198 buses of 9 m, 9571 buses of 12 m and 614 buses of 18 m long to supply the demand with fewer units. Social benefits for drivers' companies were also provided, as well as regulations for transit re-organization with new bus stops and infrastructure, synchronization of traffic lights and removal of *combis* from main avenues to gradually minimize their use [31]. The first Complementary Corridor CS03-Tacna Ave.-Arequipa Ave. was implemented in 2014, but was not well received by the population. The following corridor CS02-Javier Prado-La Marina was implemented in the same year and had the same problems as the previous one [24], which were lack of detailed information about bus stops and feeder routes and insufficient number of vehicles to cover the demand [36].

After years of pressure and speculation, the Authority for Urban Transport (ATU) for Lima and Callao was finally approved in 2018 during the presidency of Pedro Pablo Kuczynski (2016–2018). The authority will provide an integral solution for both provinces with funding from the Ministry of Transport and Communications (MTC) and the Ministry of Economy and Finances (MEF). The board will be composed of a representative from the Municipality of Lima, the Municipality of Callao, the Ministry of Housing, the MEF, and the National Police [37].

The creation of an autonomous transit authority represents a major step in transport reform. This concept appeared in European cities in the 1950s and promoted transit use through metropolitan institutions in many developed cities [8]. It is especially important In Lima because transport governance is extremely complex. The Urban Transport Management Office (GTU) of the Municipality of Lima has authority for the bus/minibus/combi routes that run throughout the city. However, the Municipality of Callao has its own Urban Transport Management Office (GTU) to regulate its own routes (although their

vehicles can traverse both jurisdictions). Additionally, the Metropolitan Institute Protransporte from the Municipality of Lima has authority over the Metropolitano and the Complementary Corridors, while the Autonomous Authority of the Mass Rapid Transit Electric System of Lima and Callao (AATE) from the Ministry of Transport and Communications (MTC) manages the Metro line [8].

While the Authority for Urban Transport (ATU) was approved by Congress in November 2018 and the start of operations was scheduled for April 2019, the project was still delayed [38]. Figure 5 [13,32,35,39] shows the distribution of the complete transit network in Lima.

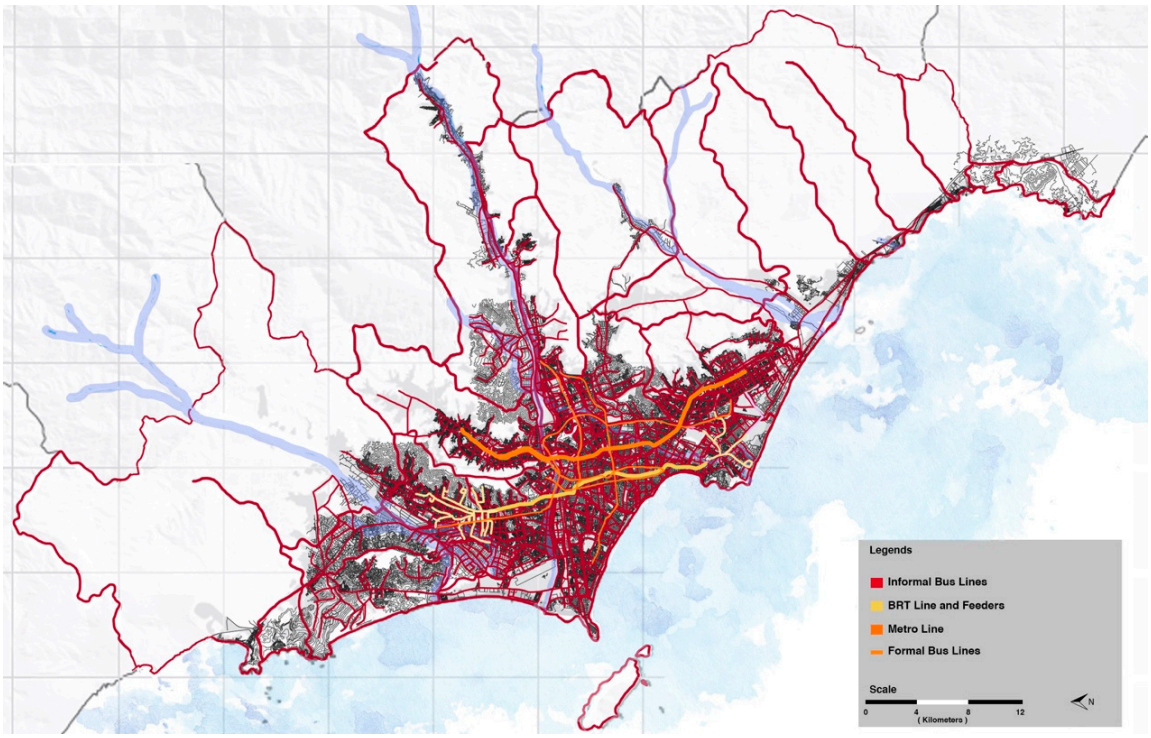

Figure 5. Metropolitan area of Lima with informal transit network, BRT, Line 1 of Metro, and Complementary Corridors (formal bus lines). Source: References [13,32,35,39]. Map by authors.

3.7. The Arrival of the Automobile, Freeways and Bypasses

At the beginning of the 20th century, the first upper-class residential neighborhoods located beyond the historic center were connected by paved streets. The first car with a gasoline internal combustion engine arrived in 1904 and by 1907 there were around 25 cars in the city [40]. During the 1920s, President Leguía's administration was influenced by the design of American cities and created new avenues from the center to the first suburban areas of Santa Beatriz, San Isidro and Magdalena and the historic balnearios of Miraflores, Barranco, and Chorrillos. He encouraged the proliferation of new neighborhoods for the middle and upper-classes, while the center remained as a place to work and study.

The Peruvian section of the Panamericana Freeway, an intercontinental freeway that runs from Chile to Alaska, was built between 1933 and 1939 during the government of President Oscar R. Benavides [41]. This encouraged the consolidation of the Southern balnearios located 60 km South of Lima and only accessible by car. The expansion of Lima during the 1940s and 1950s was accompanied and encouraged by use of the car, with a clear differentiation of uses set by the modernist city vision. In 1955, the first grade-separation (bypass) was built between Arequipa Avenue and Javier Prado Avenue. The first freeway built within the city was Paseo de la República Freeway and opened in 1967 to connect the center to the Southern district of Barranco and later with the Panamericana Sur Freeway [42], but only the first phase was built. The project was carried out during the administration of Mayor Luis Bedoya and it was expected that the metro line would travel along the reserved lane (the current route of the Metropolitano). Another important freeway was the Costa Verde around the

Bay of Lima. Bedoya used the soil leftover from the construction of Paseo de la República to create an artificial coast by reclaiming land from the sea. While this area's vision was influenced by the coastline of Rio de Janeiro, Costa Verde turned out to be a freeway at the sea level to avoid traffic at the city level. A third lane in both directions was added in 2015 during the third period of Casteñeda Lossio, shrinking the area for pedestrians and beach users. Figure 6 [13,43] shows the different freeways in the metropolitan area.

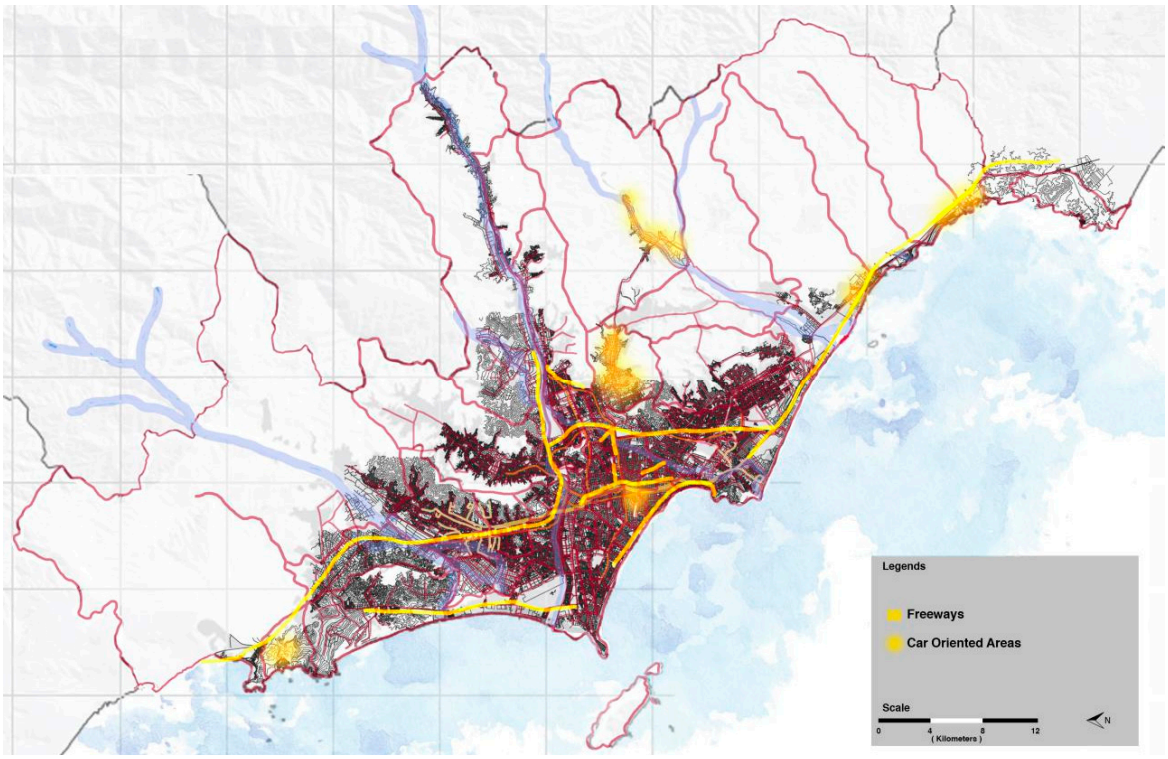

Figure 6. Lima's freeway system (Panamericana Fwy. is the only one that traverses the city). Source: References [13,43]. Map by authors.

A recent freeway megaproject is Línea Amarilla, which started construction nine years ago to connect San Juan de Lurigancho (Eastern Lima) with Callao to avoid the congestion of the Evitamiento Freeway (part of the Panamericana Freeway that runs within the city—Figure 7). The project has an extension of nine kilometers and will connect eleven districts of the city with ten viaducts and a tunnel of 1.8 km below the Rímac River. The project was supposed to be finished by 2014, but it is still under construction [44]. Castañeda Lossio also included eighteen bypasses for the Development Plan of Lima as a solution for traffic jams [45]. These monstrous pieces of road infrastructure within the city cut public space, reduced bike lanes kilometers and contributed to an entirely inappropriate vision of a city made exclusively for cars. Apart from their unsuitability, these structures remain as ineffective traffic solutions because traffic lights and nearby intersections stop their free flow. The most emblematic case of failure was the construction of the bypass of 28 de Julio in Lima Cercado, which cut a pedestrian walk and a bike lane that connected the centre with Miraflores. Such structures used to be built mainly on the periphery of Lima, also adversely affecting the urban landscape of those districts that are in greater need of high quality public space.

Figure 7. (**Left**): Panamericana Norte Freeway; (**Right**): mototaxi in Independencia district (Northern Lima). Source: Franco Jauregui-Fung (2018).

3.8. Paratransit Modes: Mototaxis

Between the 1990s and 2000, the number of taxis increased from 10,000 units to 100,000 while the number of motor-cabs (mototaxis—Figure 7) totaled more than 65,000 in the same year. These vehicles operate without being registered, through the low-income periphery of the city [26]. Paratransit modes have gained importance during the 2000s as the daily trips increased from 3.6% of all the public transit modes in 2004 to 6% in 2012 and can be seen in thirty-three of the forty-three districts of Lima. The districts of Northern Lima concentrate the largest number of mototaxis, whereas the districts without them are in Central Lima [13]. According to the president of the NGO Luz Ámbar, Law 27,189 states that municipalities have the authority for the control and inspection of mototaxis, but that is not the case. More than 40% of these vehicles are informal, do not have circulation licenses and do not respect the authorized areas of circulation [46]. Nevertheless, these paratransit modes are needed in areas where formal transit cannot reach, such as hillsides and marginal neighborhoods.

4. The Walking, Transit and Auto City Fabrics

The average density of Lima in 2018 was 141 persons per hectare (calculated with population from [1] and urbanized area from Lima Cómo Vamos [47]. Walking, Transit and Auto City fabrics are based on the respective dominant modes that are found there, which is explained in detail in Newman, Kosonen, and Kenworthy [48]. Lima's density conforms to a walking urban fabric with a density over 100 people per ha, a typical density for cities like Mumbai and Hong Kong. However, this density is uneven across the different sectors of Lima and less dense transit and car-oriented fabrics also exist.

4.1. Traditional and New Walking Cities

Before Spanish colonization, Lima was already a consolidated settlement with ceremonial centers and water canals. When the Spanish founded the city of Lima on the banks of the Rímac River, an orthogonal grid was established and was surrounded by walls during the 17th century. During both periods, the city had a walking fabric similar to today's mixed-use areas. This fabric was divided into the city for the Spanish and the Indian Reduction of Cercado (settlement created to contain the enslaved native population) [49]. The city expanded during the Republic beyond its colonial walls with construction of railways to connect the center with other walking settlements such as Callao and the former balnearios of Barranco and Chorrillos [50].

During the 20th century, new types of walking cities appeared as the neighborhood units from the Modernist Period in Lima. These autonomous collective housing centers were pedestrian-oriented with limited parking lots and equipped with services such as markets, medical centers, community centers, schools, recreation, and sports facilities with green open spaces [51]. Modernist principles were applied considering social integration and ideals of democracy and community living [52]. During the same years, a new type of walking fabric was born in Lima: The barriadas, which were first housing

places—initially without infrastructure—that were consolidated with businesses and commerce areas and appeared as local economy opportunities in the periphery [12].

4.2. The Transit Fabric

Transit areas were rapidly created with the appearance of trains and trams during the second half of the 19th century and since then, Lima has been dependent on transit modes. Such was the demand (and the failure of government to provide adequate formal transit), that informal transit appeared as early as the 1930s as an alternative to the formal modes [13]. When trams stopped circulating around the city in 1965, buses were already spread all over the city to connect the recently urbanized areas with the center, where most of the economic, political and social activities took place. The remotely located barriadas or pueblos jóvenes (young towns) used these informal transit routes to travel to the center. During the 1990s, and with the removal of the formal transit modes such as ENATRU, informal buses, minibuses and combis assumed the role of connecting the whole urban area, which extends from the center to Northern, Eastern and Southern Limas, and Callao, with no non-urbanized land left between them today. The 21st century brought the return of formal mass transit with the introduction of Metropolitano (BRT) and the opening of Line 1 of Metro, which became the first systems with reserved routes in Peru (i.e., alignments fully protected from general road traffic and hence traffic congestion).

4.3. Suburban Lima and Balnearios

With the introduction of the car at the beginning of the 20th century, Lima was influenced by an American lifestyle, expressed in the new axes that connected the center with the new residential areas. The upper-class left the central city for the Southern low density areas with single-family homes along the new avenues, but still commuted there for work purposes. After the traditional upper-class areas were surrounded by middle-class neighborhoods during the 1950s, the wealthy moved once again to the eastern suburbs of Monterrico and La Molina onto big lots without easy access by foot or transit. Both periods of urbanization were accompanied by use of cars, which in turn increased the exclusiveness of these residential areas as this meant longer travel distances and higher fuel costs to get to education, recreation and work [22]. The center was still the work place for the upper-class until the San Isidro CBD was created in the 1990s. The summer resorts outside the city were also conceived as car fabrics since they were consolidated once the Panamericana Sur Freeway was built in the 1930s. These balnearios have continued their urbanization process due to the economic growth of the 1990s and 2000s and have become seasonal residential areas for the upper-class during summertime.

4.4. Walking, Transit and Automobile Fabrics Today

The current situation of these fabrics is very similar to their origins. Although the historic center has currently only minor residential use, other traditional walking fabrics are still intensely inhabited such as Callao, Barranco and Chorrillos. The now consolidated barriadas continue as walking fabrics that are connected to other areas of the city through the BRT and metro, but mostly through informal transit.

Following the principle of high densities in walking fabrics [48], twenty-seven districts of Lima present densities over 100 people per hectare (Table 3 [13]). While thirteen districts from Central Lima are part of this list, it is important to note that the other fourteen districts belong to the periphery (Callao and Lima Conurbana). This means that unlike European cities, Lima's periphery also contains dense fabrics. Regarding transit fabric with minimum densities of 35 people per hectare, eleven districts present densities above that figure. Once again, these densities can be found in Central Lima as well as in the periphery. Finally, the eleven remaining districts report densities below 35 people per hectare, which conforms to auto city fabrics, though at 26 persons per ha, these are higher than typical auto city fabric densities in the US and Australia (Table 4 [1,24,34,39,47,53–63] below). These peripheral districts are traditional seasonal recreational areas for the wealthy. Pachacamac, Chosica and Cieneguilla are countryside districts from Eastern Lima, while the balnearios districts have the lowest densities in the metropolitan area with an average of 19 persons per hectare.

Table 3. Categorization of Lima's Districts into Walking, Transit, and Automobile fabrics according to their density in 2010.

Walking Fabrics					Transit Fabrics				
District	**Population**	**Area (Ha)**	**Density**	**Sector**	**District**	**Population**	**Area (Ha)**	**Density**	**Sector**
Breña	81,909	321	255	Central Lima	Miraflores	85,065	916	93	Central Lima
Carmen De La Legua	41,863	192	218	Callao	Santiago De Surco	289,597	3157	92	Central Lima
La Victoria	192,724	910	212	Central Lima	Chorrillos	286,977	3261	89	Southern Lima
Independencia	207,641	1000	208	Northern Lima	Callao	415,793	4883	86	Callao
Lince	55,242	275	201	Central Lima	Ventanilla	277,895	3789	74	Callao
Rímac	176,169	901	196	Central Lima	La Punta	4370	60	74	Callao
Surquillo	89,179	462	193	Central Lima	Carabayllo	206,951	2959	70	Northern Lima
La Perla	61,698	329	188	Callao	Puente Piedra	233,602	3486	68	Northern Lima
Santa Anita	184,614	1034	179	Eastern Lima	San Isidro	58,032	971	60	Central Lima
San juan de Miraflores	362,643	2080	175	Southern Lima	Chaclacayo	41,110	786	53	Eastern Lima
Los Olivos	318,125	1827	175	Northern Lima	La Molina	132,498	3009	45	Central Lima
San Martín de Porres	579,479	3519	165	Northern Lima	**Total transit fabrics**	**2,031,890**	**27,277**	**75**	
Bellavista	75,163	458	165	Callao	**Automobile Fabrics**				
Pueblo Libre	74,164	463	161	Central Lima	Pachacamac	67,489	2097	33	Southern Lima
El Agustino	180,262	1131	160	Eastern Lima	Chosica	169,316	5816	30	Eastern Lima
San Luis	54,634	349	157	Central Lima	Ancón	33,367	1167	29	Balnearios
Magdalena Del Mar	50,764	327	156	Central Lima	Pucusana	10,496	378	28	Balnearios
Jesús María	66,171	434	153	Central Lima	San Bartolo	5708	232	45	Balnearios
Comas	486,932	3330	147	Northern Lima	Santa Rosa	10,903	541	21	Balnearios
San Juan De Lurigancho	898,101	6178	146	Eastern Lima	Cieneguilla	26,488	1384	20	Eastern Lima
Lima	299,412	2159	139	Central Lima	Lurín	61,246	3350	19	Southern Lima
San Miguel	129,107	960	135	Central Lima	Punta Hermosa	5423	333	17	Balnearios
Villa María Del Triunfo	378,449	2964	128	Southern Lima	Punta Negra	5283	403	14	Balnearios
Barranco	33,903	275	124	Central Lima	Santa María Del Mar	133	71	2	Balnearios
Villa El Salvador	381,790	3334	115	Southern Lima	**Total car fabrics**	**395,852**	**15,772**	**26**	
Ate	478,278	4421	109	Eastern Lima					
San Borja	105,076	1029	103	Central Lima	**Metropolitan Lima**	**8,471,234**	**83,711**	**102**	
Total walking fabrics	**6,043,492**	**40,662**	**150**						

Source: [13].

Table 4. Key comparative urban data for Lima and averages for other groups of world cities.

Indicator	Unit	Metropolitan Lima	USA	Australia	Canada	Europe	Asia
			2005	2006	2006	2005	2005
Characteristics of Metropolitan Area							
Urban density	persons/ha	136 (2015)	16	15	26	48	218
Gross Domestic Product per capita	USD/person	6405 (2015)	44,455	32,194	31,263	38,683	21,201
Transport Supply Indicators							
Length of reserved public transport routes per 1000 persons	m/1000 persons	6 (2012)	72	160	67	298	34
Length of freeway per capita	m/person	0.021 (2015)	0.156	0.083	0.157	0.094	0.026
Private vehicle ownership per 1000 persons	units/1000 persons	259 (2015)	656	667	537	503	98
Mobility Indicators							
Annual public transport vehicle kilometres of service per capita	v.km/person	146 (2015)	39	59	52	108	134
Annual private passenger vehicle kilometres per capita	v.km/person	1422 (2015)	13,176	8770	6573	5060	1575
Annual public transport passenger kilometres per capita	p.km/person	3287(2015)	571	1075	1031	2234	3786
Annual private transport passenger kilometres per capita	p.km/person	3026 (2012)	18,784	12,526	8554	6950	2265
Percentage of daily trips by non-motorised modes*	%	25 (2012)	10	14	12	35	26
Percentage of daily trips by public transport*	%	49 (2012)	5	8	13	22	46
Percentage of daily trips by private transport*	%	26 (2012)	85	78	75	43	28
Total daily trips per capita*	trips/person	2.36 (2012)	3.68	3.36	2.74	3.21	2.56
Annual public transport boardings per capita	boardings/person	449 (2015)	67	96	151	386	450
Transport Externality Indicators							
Annual emissions per capita	kg/person	23 (2004)	185	144	165	35	34
Annual transport deaths per 100,000 people	deaths/100,000 persons	4.8 (2015)	9.5	6.2	6.3	3.4	3.8
Public-Private Transport Balance Indicators							
Ratio of segregated public transport infrastructure versus expressways		0.29 (2012)	0.56	1.98	0.56	5.51	1.42
* Daily trips values don't consider "Trucks and other modes" or "Camión y Otros" (44,000)							

Note: Cities included in averages are: USA: Atlanta, Chicago, Denver, Houston, Los Angeles, New York, Phoenix, San Diego, San Francisco, Washington; AUSTRALIA: Brisbane, Melbourne, Perth, Sydney; CANADA: Calgary, Montreal, Ottawa, Toronto, Vancouver; EUROPE: Berlin, Bern, Brussels, Copenhagen, Düsseldorf, Frankfurt, Geneva, Graz, Hamburg, Helsinki, London, Madrid, Manchester, Munich, Oslo, Prague, Stockholm, Stuttgart, Vienna, Zurich; ASIA: Hong Kong, Singapore. Source: [1,24,34,39,47,53–63]. Table by authors.

Notwithstanding that half of the districts present rather dense fabrics (average of 150 per hectare), it cannot be assumed that Lima is in fact a walking city because the distances people need to travel to work and study are large. However, with 25% of all daily trips by non-motorized modes, there is a beneficial density effect for many local trip purposes. On the other hand, eleven districts have densities typical of transit fabrics (average 75 per hectare), which benefit from extensive informal transit, as well as the recent formal mass-transit modes (BRT and metro). Both informal and formal modes contribute to the interconnection of the walking and transit fabrics, which still rely on the economic and productive centers in Central Lima and the high-density transit fabric helps to explain Lima's high transit use (Table 4 [1,24,34,39,47,53–63] below). The population of the automobile fabrics also depends on the traditional centers for working, studying, shopping, and entertainment. Figure 8 [13] shows the density distribution in Metropolitan Lima and reveals peripheral dense concentrations.

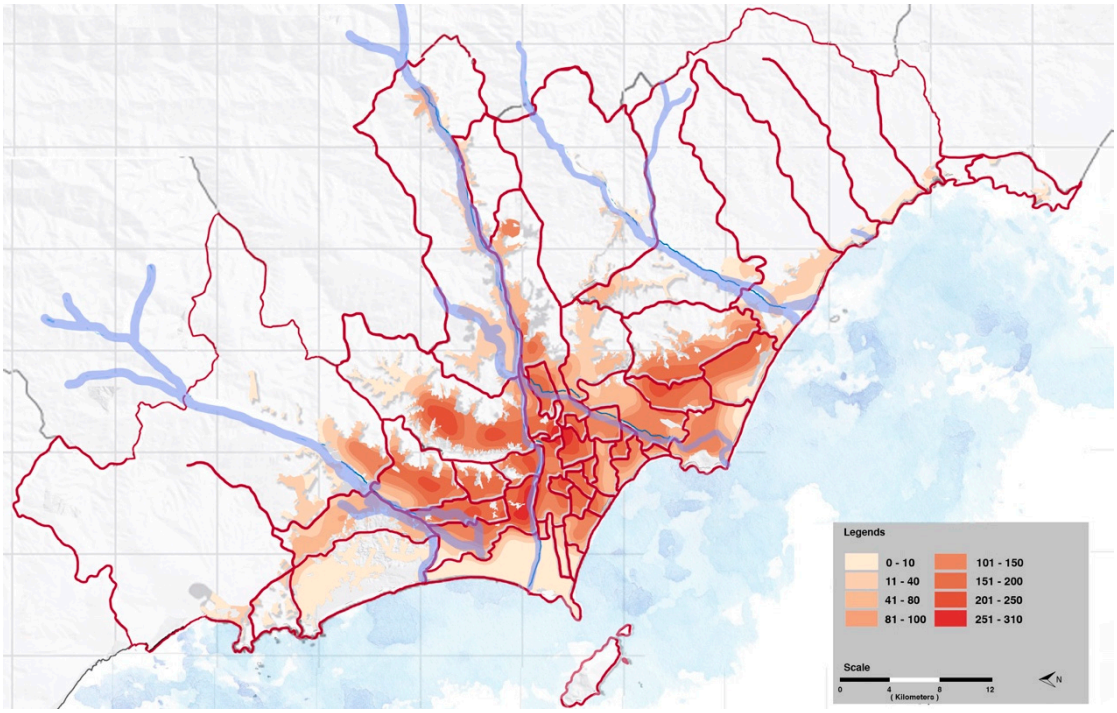

Figure 8. Densities of Lima's urbanised area. Source: Reference [13]. Map edited by authors.

5. How Does Lima Compare to a Sample of Other World Cities and What Strengths, Weaknesses and Policy Lessons Does This Reveal for Now and the Future?

Having discussed the physical and transport evolution of Lima, it is useful from a planning and policy perspective to compare its current situation to the recent situation of a selection of other world cities. A variety of key data was collected to calculate a series of normalized, comparative urban indicators. Such international comparisons of cities are complex, but have a publishing history spanning almost 40 years. The history of this methodology and its efforts to ensure comparability of data across cities is described in detail in Kenworthy [64].

The most recent available data for mobility in Metropolitan Lima were collected and standardized to analyze the city's mobility strengths and weaknesses and used to position Lima in a global context on each indicator. These comparisons show key issues facing Lima today and point to some fundamental policy priorities for the future. The indicators are summarized in Table 4 [1,24,34,39,47,53–63] and discussed individually, with graphics where relevant to make key comparisons clearer.

5.1. Status of the Information

Data collection was based on inventories and surveys by international, national, and municipal institutions. The main ones were the Japan International Cooperation Agency (JICA), National Institute of Statistics and Informatics (INEI), Metropolitan Institute Protransporte from the Municipality of Lima, the Metropolitan Plan of Urban Development (PLAM2035) from Susana Villarán's management (2011–2014) and the urban laboratory Lima Cómo Vamos. Surveys made by transport authorities in charge of the Metro and *Metropolitano*, such as the Autonomous Authority of the Special Project for the Mass Rapid Transit Electric System of Lima and Callao (AATE) were also reviewed. However, due to the relative scarcity of certain updated primary data, the data collection was focused around 2012, but some information from 2004, 2015, and 2016 was also included, simply because these were the most relevant years to the chosen focus year of 2012. In addition, most of the sources rely on the survey made by JICA for 2004, and updated in 2013. Some growth factor calculations were also carried out to find data for the missing years. Normalized data provided by Schiller and Kenworthy [63] for representative cities were used to position Lima in a global context.

5.2. Characteristics of the Metropolitan Area

The metropolitan region formed by the Province of Lima and the Constitutional Province of Callao is over 80 km from North to South [65], however, there is a considerable difference between the urbanized land and the whole metropolitan region. In 2016, the metropolitan region accounted for 267,250 hectares whereas the urbanized area was only 73,100 hectares (less than one-third of the total area [47]). In 2015, the urban density was 136 people/hectare [47,57]. Lima is not only the most populated city in Peru, but is also the fifth largest in Latin America and one of the top thirty in the world [66]. Additionally, the region plays a dominant role in the national GDP. In 2016, Lima was responsible for 41% of the total GDP of Peru [58], while in 2015, the GDP per capita was 6405. USD/person [58] (deflated to 1995 US dollars to compare it with the other cities). However, it also presents the greatest inequality in Peru between the richest and the lowest income sectors.

5.3. Supply Indicators

Regarding transit infrastructure, the length of reserved routes for transit was measured: the BRT (Metropolitano) is 26 km [34] while the above-ground Line 1 of the Metro is 34 km [24], a total of 60 km. This represents only 30% of the length of freeways. The length of reserved routes for transit per 1000 people in Lima represents the lowest value amongst the chosen other cities, with a total of 6.4 m per 1000 persons (Figure 9 [47,57,63]). Of these, 2.8 m belong to the Metropolitano and 3.6 m to the metro line. The other transit modes (buses, minibuses and combis) share the streets with private modes without reserved rights-of-way, which reduces the speed and increases the trip times for these modes.

This is one of the most basic problems facing cities that rely on informal transit systems—they do not develop rights-of-way for transit that allow it to reliably keep to timetables and to provide attractive services that compete in speed terms with the car and motorcycle. Provision of reserved rights-of-way (buses and rail) requires a high level of planning, involvement of government and coordinated governance systems, which means they are the province of formal transit systems. As incomes and expectations rise, reserved rights-of-way are key to maintaining, and growing transit use [63].

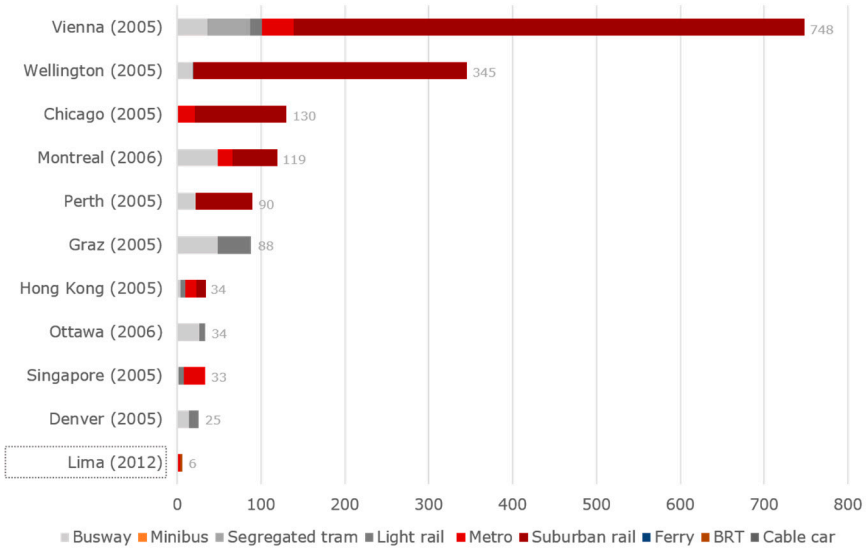

Figure 9. Length of reserved transit routes per 1000 people (m/person). Source: References [47,57,63]. Graph by authors.

The total length of freeways (205 km) was collected by adding up their center-line lengths in the metropolitan area (i.e., roads without traffic lights, with no vehicle intersections, and with no direct property access from the road) using Google Maps [43]. Unlike car-oriented cities with a network of freeways, these are mostly disconnected from one another and do not make a system. In 2012, the total length of freeway per person (m/person) was 0.020, and the total length of freeway per urban area (m/ha) was 2.8. In comparison with the other cities, Lima has one of the lowest lengths of freeway per person (Figure 10 [43,57,63]). Lima shares this feature with great transit metropolises such as London, Hong Kong and Singapore (Figure 10 [43,57,63]). Freeways increase automobile dependence in cities so Lima should maintain its low freeway provision and cease adding further to the system.

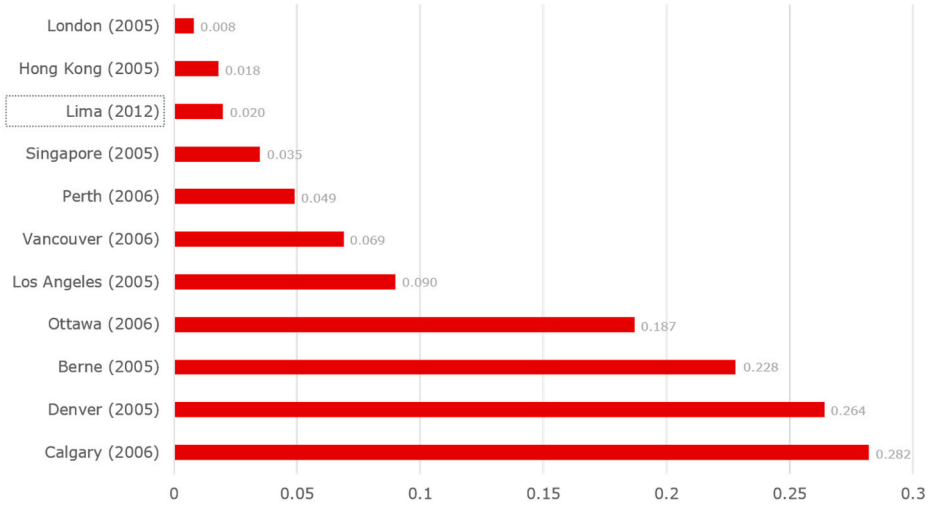

Figure 10. Total freeway length per person (m/person). Source: [43,57,63]. Graph by authors.

Private transport supply in this paper includes private cars, taxis, motorcycles and mototaxis, (all relatively low capacity modes of a private nature), although it is a grey area regarding how to classify them. Depending on the perspective taken, taxis in lower income cities and mototaxis can also be classed as informal transit or "paratransit" due to the often-shared nature of their operations. In the international data used in this paper, such modes have been excluded from transit and this was maintained here for comparative purposes. According to Lima Cómo Vamos [47], private car

ownership (4-wheelers) includes light vehicles (777,513), station wagons (258,131), pick-ups (157,741) and taxis (118,201). In Lima, taxis are private modes that are also informal as they are individually owned instead of being run by a company. Private vehicle ownership is 259 vehicles per 1000 persons for Metropolitan Lima, a value well below car-oriented cities such as Denver or Perth. On the other hand, private vehicle ownership in Lima is still four times higher than in Hong Kong, the city with the least private vehicles per capita in this sample of cities (Figure 11 [34,47,57,63]).

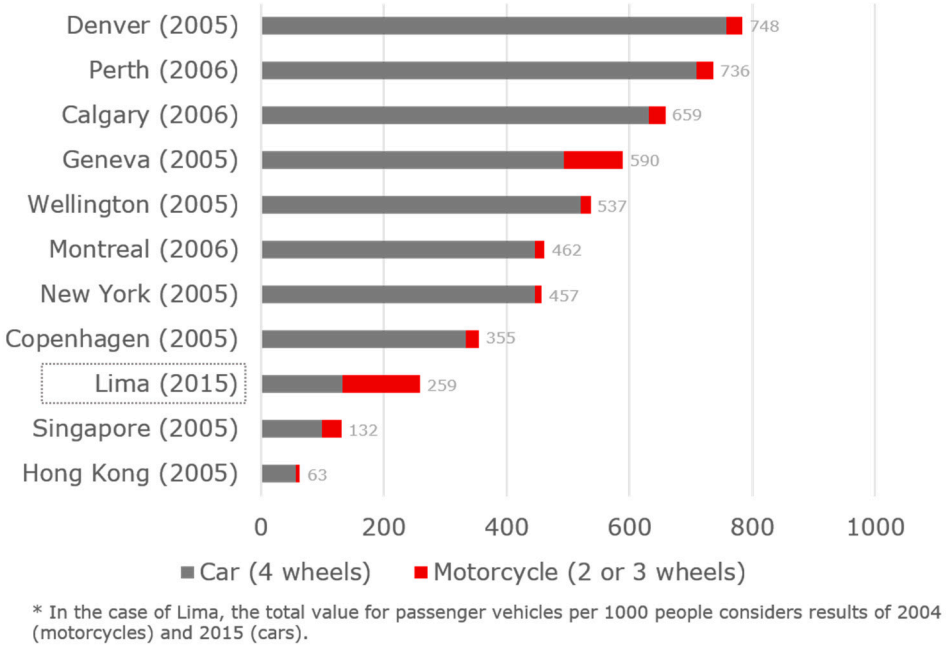

Figure 11. Private passenger vehicles per 1000 people (units/1000 people). Source: References [34,47,57,63]. Graph by authors.

The data confirm that Lima has already developed high private vehicle ownership relative to its low GDP compared to other world cities (e.g., the two Asian transit metropolises average 98 private vehicles per 1000 persons with a GDP per capita of $21,201, while Lima averages 259 vehicles per 1000 persons with a GDP of $6405 per person—Table 4 [1,24,34,39,47,53–63]). This suggests, among other things, that the low service quality of informal transit systems tends to push people towards cars and motorcycles at an earlier stage of economic development. Most users of informal transit are captive riders, who once able to afford a motorcycle or car will tend to do so. Conversely, high quality formal transit systems as in Hong Kong and Singapore show how private vehicle ownership can be kept to very low levels despite relatively high GDP per capita, especially when combined with economic restraints on car ownership and use [63].

Figure 12 [13,39] compares car and mototaxi ownership in the city. Lima's low car ownership is concentrated in middle and upper-class households (Figure 13 [39]). Cars are owned in 66% of families with a monthly income between 3400 and 9000 PEN (1254 and 3318 USD, values in 2013), and in 93% of families with a monthly income above 9000 PEN (3318 USD, value in 2013). JICA [39] reported that more than 30% of homes in Central Lima own more than one car, whereas this value in Lima Conurbana is less than 10%. Automobile ownership in the balnearios and in suburban districts from Eastern Lima helps to confirm these areas as automobile city fabrics. Motorcycle (2-wheelers) and mototaxi (3-wheelers) ownership is 1,252,373 [34]. Based on the survey carried out by Technical Secretariat of the Transport Council for Lima and Callao (ST-CTLC), in 2009 there were 21,663 mototaxis in the city which were mainly located in Northern Lima (7794 vehicles), Eastern Lima (7196 vehicles) and Southern Lima (5397 vehicles) [13]. This reveals that the localization of paratransit ownership is

opposite to the centralized localization of car ownership. This number increased to around 600,000 mototaxis in 2016 [46].

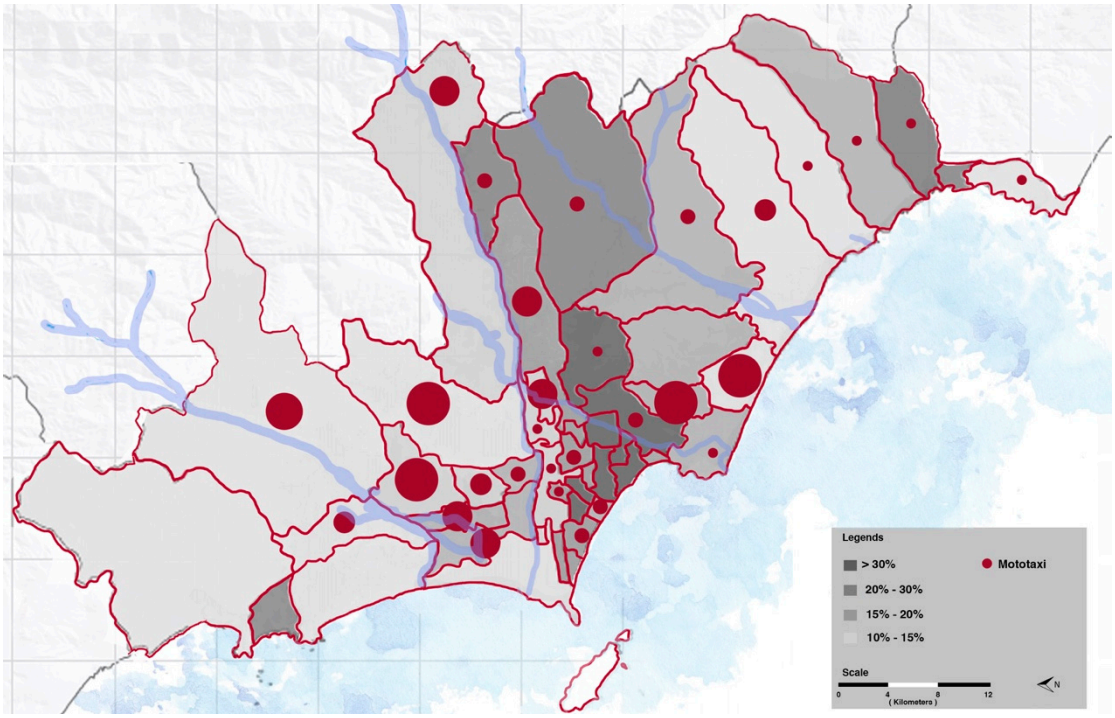

Figure 12. Comparison between car and mototaxi ownership in Lima. Source: References [13,39]. Map by authors.

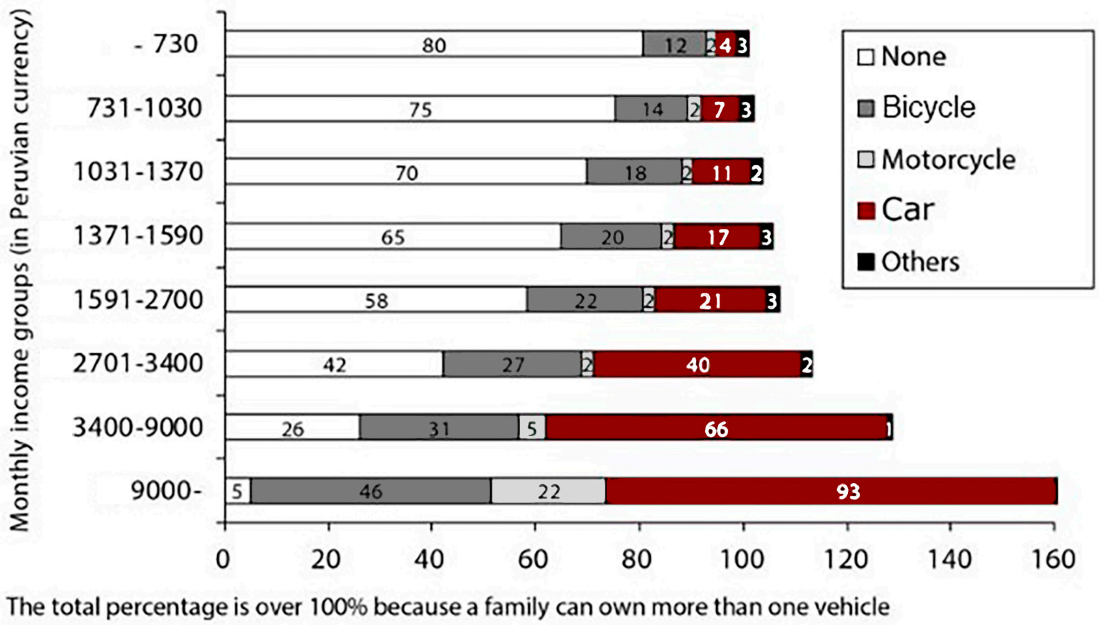

Figure 13. Vehicle ownership according to monthly income. Source: Reference [39]. Graph edited and translated by author.

We conclude from these data that, although Lima concentrates 66% of Peru's vehicle fleet [67], it is not an automobile-oriented city because of the comparatively low car ownership and short length of disconnected freeways that do not enable easy car circulation. In addition, the high number of mototaxis implies the existence of strong localized mobility options that are in the paratransit category,

not private motorized vehicles (i.e., motorcycles and cars). This relatively low overall private transport orientation can, however, be a fragile situation. Peru and other Latin American countries' emerging economies are increasing motorization levels [7]. Unless more is done to limit or end the growth in freeways, an increase in the transit options that are attractive to residents as incomes and expectations grow, and to place economic imposts on motorcycles and cars, motorization will continue to pose a great challenge.

5.4. Mobility Indicators

The mobility indicators aim to compare transit and private transport modes in Lima through modal splits, total annual vehicle kilometers of travel (VKT) and total annual passenger kilometers (PKT). According to Schiller and Kenworthy [63], VKT represents the distance driven by vehicles (be they cars, motorcycles, taxis or other forms of private mobility) by residents of the studied area in one year. VKT can also be measured for buses, trains, ferries, and other modes, private or public. PKT is the total distance travelled by people utilizing any of these modes and in the case of private cars is derived typically by multiplying the annual VKT of cars by the average car occupancy (e.g., 1.5 persons per car—a 24 h per day, 7 days per week figure). PKT can also be calculated by multiplying the total number of person trips in one year in any mode (e.g., cars) with an average trip length in kilometers for that mode. PKT can also of course be measured for transit modes. This is either directly available from transit operators for each mode, or calculated by multiplying the number of annual boardings by the average length that each boarding travels.

Comparing the percentage of usage by the different transport modes in Lima (Figure 14 [39]), informal and formal transit (combi, bus, minibus, BRT and metro) represent 49% of the total daily trips, whereas the informal and formal private modes (private car, colectivo, taxi, motorcycle, and mototaxi) and the non-motorized modes (foot and bicycle) come in second and third place with 26% and 25%, respectively [39]. Private motorized modes thus accounted for only one-quarter of the mobility needs of the citizens of Lima in 2012.

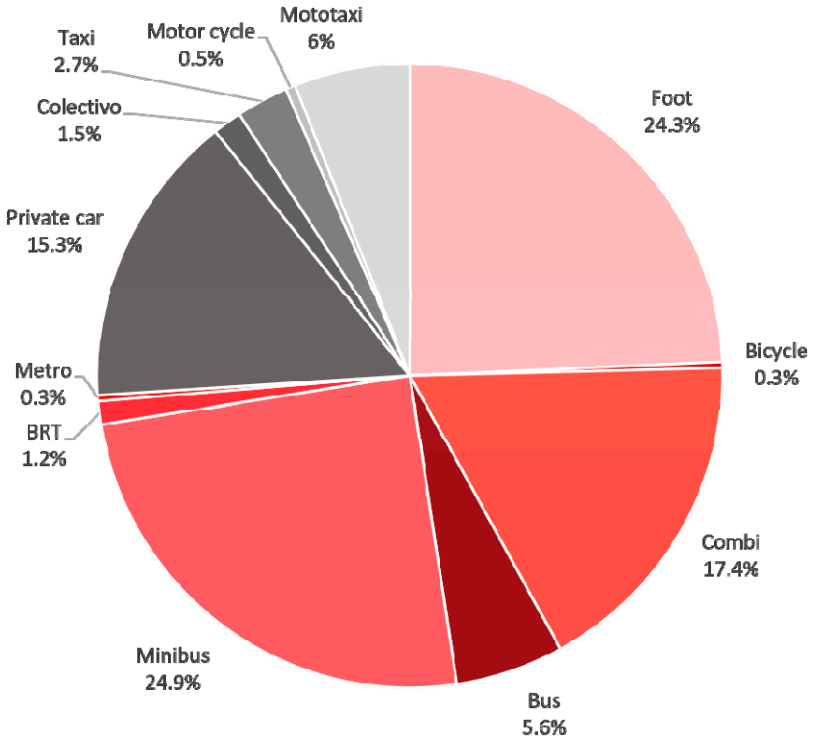

Figure 14. Percentage of daily trips by each transport mode in Metropolitan Lima, 2012. Source: Reference [39]. Graph by authors.

Referring to Table 4 [1,24,34,39,47,53–63], in 2012, there were 449 annual transit boardings per capita in Lima, a high figure globally (informal transit—buses, minibuses and combis—was 412 per person [39,57], and formal transit—Metropolitano, Line 1 of Metro and the Complementary Corridors—constituted only 20 [34,57], 12 [53,57], and 5 [34,57], respectively). Informal transit thus represents more than 90% of total transit demand. This matches its annual service level provided (VKT per capita) which is more than 30 times higher than the formal transit modes combined (141.6 km travelled per person in 2015 [34,57], compared to the Complementary Corridors of 2.5 km per person [57,61] and the BRT and the metro with 1.4 [1,60] and 0.3 km [53,57], respectively).

These data again emphasize the huge dependence of Lima on informal transit modes. It needs to be said, however, that high VKT per capita of service in informal modes is essential and unavoidable because of the low capacity vehicles that they use. Without high kilometers of service, they would not be able to accommodate the travel demand placed upon them. Regular transit using much bigger vehicles could achieve a similar capacity offer with much less VKT. Additionally, as already mentioned, the Penny War system obligates bus drivers to make as many trips as possible to make profit.

Regarding private modes, although in 2015 the number of private cars per 1000 people (132) [47,57] and the number of motorcycles and mototaxis per 1000 people (126) [34,57] is similar, 4-wheel vehicles are mainly used for longer distances. VKT in private cars per capita accounts for 1209 (vehicle km/person) [55,57], which is five times more than the distance travelled in motorcycles and mototaxis (213 vehicle km/person) [55,57] such that VKT in private cars represents 85% of total VKT in private modes. Similarly, there were 24 billion annual passenger car passenger kilometers of travel (PKT) in 2012 [39,56], six times more the annual PKT in motorcycles/mototaxis (4 billion PKT) [39,55,56].

When comparing the VKT between the private and transit modes, it is possible to note that the private distance travelled of 1422 vehicle km/person [55,57] is almost ten times higher than the annual travel distance per capita of the transit modes altogether, which is 146 vehicle km/person [1,34,53,57,60–62]. Comparisons of VKT between private and transit modes is of course less meaningful than PKT because of the vastly different loadings involved between these two modes (less than two persons per vehicle in private modes generally, versus often 20 persons per vehicle or more on average in public modes, depending on the vehicle type [68]. Therefore, in PKT, transit reaches 3287 passenger km/person [39,57,59] compared to 3026 passenger km/person [39,55,57] for private transport due this big difference in loadings.

These data position Lima as a metropolitan region with a solid use of transit and they also show that the private modes are causing most congestion and consuming vastly greater amounts of road space than is available. Public motorized modes constitute only 9% of the combined public and private vehicle kilometers driven in Lima and yet account for 52% of all motorized passenger kilometers travelled, while conversely private motorized modes account for 91% of all motorized vehicle kilometers and yet transport only provides 48% of all motorized movement.

This raises fundamental questions about crucial topics such as the budgets for different modes (e.g., investing in roads versus investing in far more space-efficient transit) and questions of equality and indeed morality. Why are private modes given pride of place in a mobility system in which their usage is significantly disproportionate to their huge impacts on congestion, air pollution, noise, despoiling of public space, and their consumption of scarce transport capital funding resources?

In a global context, Lima's private PKT is the second smallest when compared to car-oriented cities (such as Perth and Atlanta) and transit-oriented cities (such as Singapore and Brussels), surpassing only that of Hong Kong. By contrast, the public PKT is the third highest in the same comparison, after Hong Kong and Berne (Figure 15 [39,55,57,59,63]). The VKT is similar with Lima, having the second smallest value for private modes (Figure 16 [55,57,63]) and the third highest for transit modes (Figure 17 [34,53,57,60–63]).

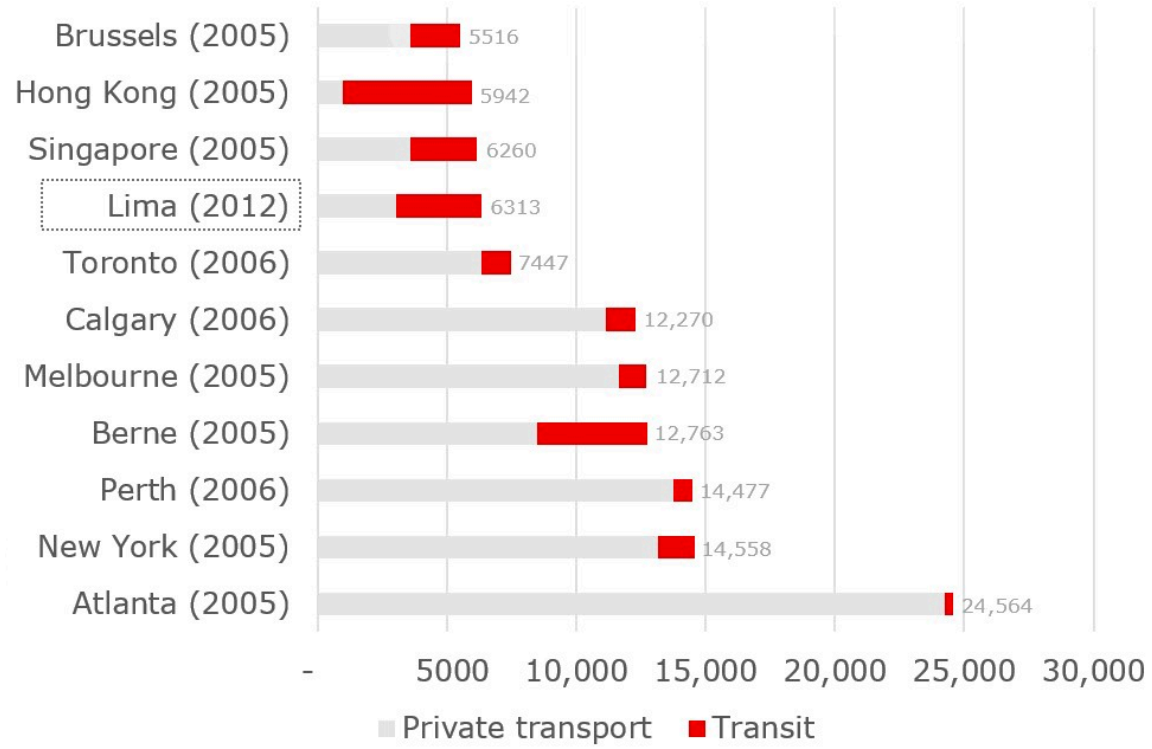

Figure 15. Total private and transit passenger kilometers per capita (passenger km/person) in world cities. Source: References [39,55,57,59,63]. Graph by authors.

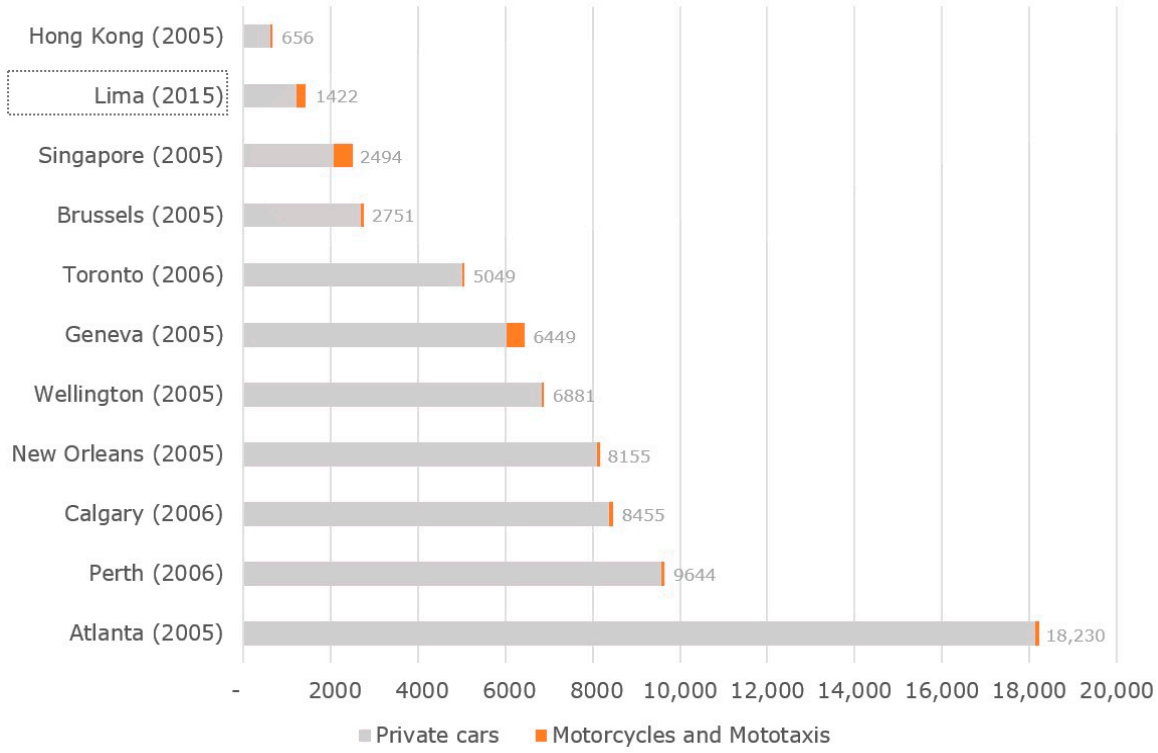

Figure 16. Total private transport vehicle kilometers per capita in world cities (vehicle km/person). Source: References [55,57,63]. Graph by authors.

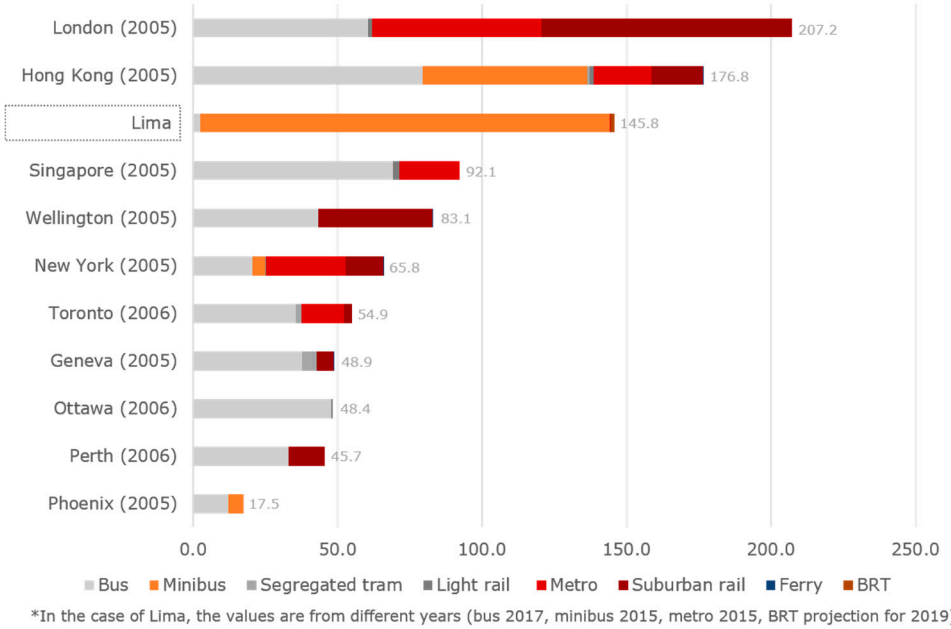

Figure 17. Total transit vehicle kilometers of service per capita in world cities (vehicle km/person). Source: References [34,53,57,60–63]. Graph by authors.

From the data, it can be concluded, and rather positively, that Metropolitan Lima is for the most part transit-oriented. However, this is negatively colored by the fact that, it is still very much dependent on less comfortable, less attractive, less speed-competitive and to a degree, less safe informal transit modes. Such modes tend to be the first to be abandoned as peoples' income and expectations rise. Keeping transit use high in the face of growing wealth ultimately depends on continuously improving the quality, comfort and reliability of transit so that it competes with private modes. As shown in Table 4, the wealthy European cities ($38,683 GDP per capita, six times that of Lima) have maintained very high use of transit based entirely upon highly developed, good quality, integrated and well-managed formal transit systems, which serve both captive and choice riders.

One indicator of this lack of transit service quality in Lima is that the length of exclusive transit lanes compared to the length of freeways is only 0.30, while for example in the European cities the figure is reversed with three time more exclusive transit lanes than freeways. This also suggests that public funds in Lima are prioritized towards private modes, thus worsening transit quality through lack of investment.

5.5. Origin-Destination Trips

Figure 18 [69] shows that 74.6% of trips in Lima are related to work purposes, followed by 21.4% to go to study centers. Trips to go back home were excluded in the calculation and all walking trips were also excluded. Furthermore, the average distance of the trips to go to work is 16 km with an average travel time of 62 min or a little less than 16 km/h [69], an average speed typical of what can be achieved in a city on a bike, where the city has at least some bicycle-only lanes. However, more than 97% of passengers that travel in transit modes spend more than two hours a day travelling [59]. This shows a great difference between people who live closer to their work places. People who live less than 16 km away from their work places spend 44 min to travel the average distance of 9.4 km (12.8 km/h). In contrast, the average distance travelled by people who live more than 16 km away from their workplaces is 26.8 km and they spend 92 min to travel that distance, though they travel faster (17.5 km/h) [69]. The average time of local trips carried out in mototaxis is 9.9 min [13].

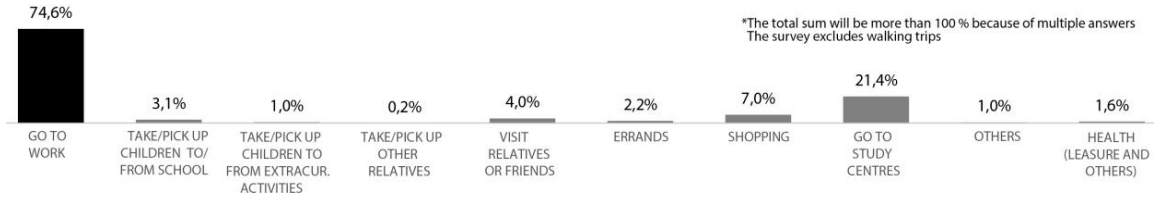

Figure 18. Trip purposes in Lima. Source: Reference [69]. Translation by authors, 2018.

Central Lima contains the highest densities of employees, especially in the Miraflores business area and San Isidro CBD. JICA's report from 2004 and collected by the PLAM 2035 [13] showed that most destinations of motorized trips were in Central Lima (Table 5 [13]). This can also be seen in the desire lines of travel (Figure 19 [39]), which are directed towards Central Lima, especially in the axis formed by the districts of Lima Cercado, San Isidro and Miraflores, having a length of around 7 km (within a city with an extension over 80 km) [65]. This means that a significant proportion of these trips would be under 7 km and could be comfortably made by bike if bicycling could be made safe and attractive and a culture of cycling developed.

Table 5. Number of daily trips in motorized modes between the Four *Limas* and Callao.

Origin -> Destination	Center	North	South	East	West	Total
Center	3,175,000	611,000	487,000	730,000	283,000	**5,286,000**
North	616,000	1,289,000	41,000	97,000	141,000	**2,186,000**
South	494,000	39,000	966,000	67,000	21,000	**1,588,000**
East	733,000	97,000	67,000	1,281,000	43,000	**2,224,000**
West	285,000	141,000	22,000	44,000	548,000	**1,040,000**
Total	**5,303,000**	**2,178,000**	**1,585,000**	**2,223,000**	**1,036,000**	**12,324,000**

Source: Table redrawn by authors with data from reference [13].

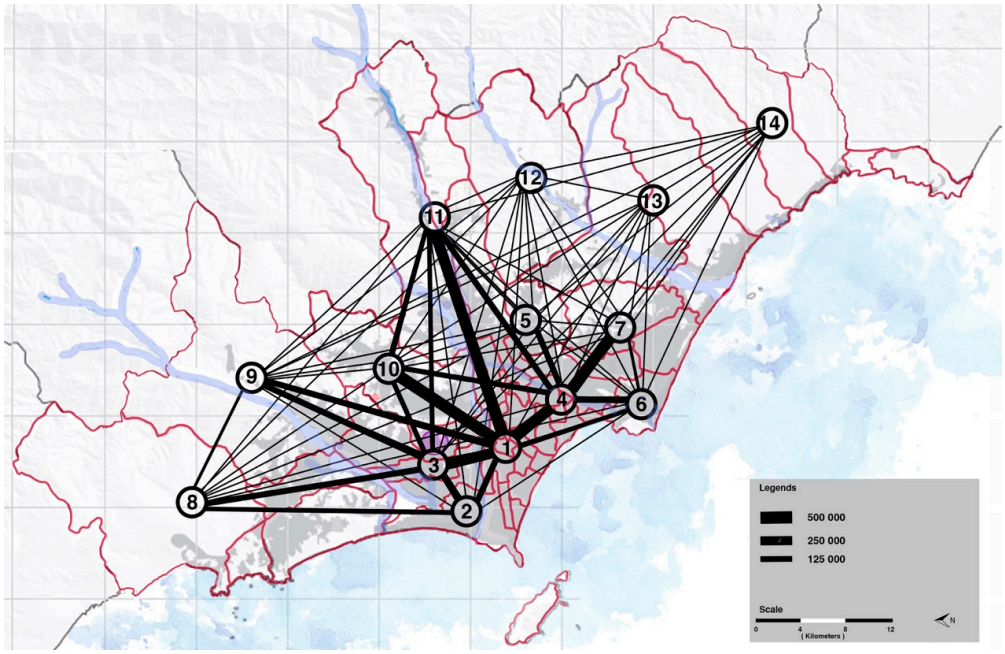

Figure 19. Desire lines according to the different areas of Lima. All transport modes included. Source: Reference [39]. Map by authors, 2018.

A survey made by the Research Centre for Architecture and City (CIAC) of the Pontifical Catholic University of Peru (PUCP) and shown in Figure 20 [65] revealed that only in Central Lima, 72% of the trips for work purposes were carried out within Central Lima [65]. In contrast, around 50% or more of citizens who live in the periphery need to travel outside their sector of residence to go to work. This implies trips with a distance that may exceed 16 km. Regardless of the geographic sector, more than 50% of work trips are carried out using transit modes [65]. Work trips carried out in private cars are the highest in Central Lima (21%), whereas the highest percentage of walking trips to work is in Northern Lima (20%) [65], which implies the possibility of local work opportunities. In contrast, for shopping trips, more than 50% of these are carried out within the same sector of residence (Figure 20 [65]). Except for Southern Lima with 57%, the difference between Central Lima and the other sectors is not very significant (between 72% and 83%) [65]. This suggests that the offer of malls, markets and retail shops is diverse, but also more homogeneous across the city, in comparison to the localization of work [65]. Once again, the highest transport mode for shopping trips is transit. However, except for Southern Lima, walking caters for over 20% of shopping trips and is much higher than cars [65].

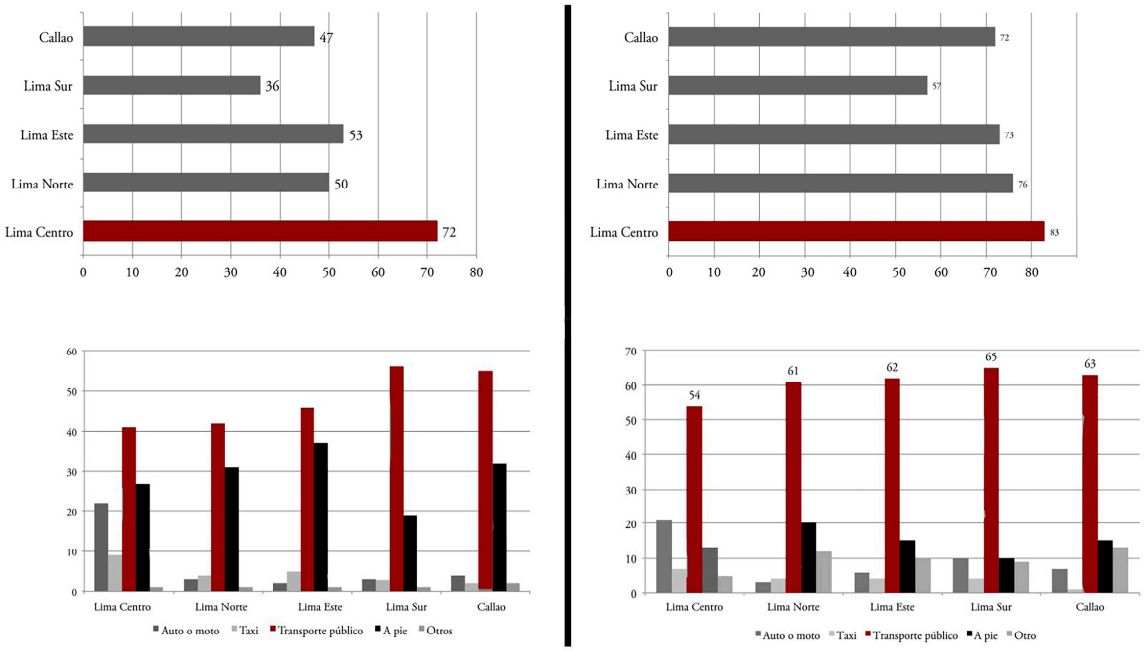

Figure 20. (**Left**): Total percentage of trips for working within same sector and chosen mode by sector of residence. (**Right**): Total percentage of trips for shopping within same sector and chosen mode, by sector of residence. Source: Reference [65] Translation by authors.

This tends to confirm Chion's [16] theory about Polycentric Lima in the offer of shopping, but is refuted in the localization of employment and denies the possibility of metropolitan centralities in peripheral areas [65]. This job concentration within Central Lima also explains why a high percentage of the population spends more than two hours a day travelling. This finding, along with the localization of car ownership in Central Lima increases traffic jams in the traditional centers of the city (Figure 21).

Figure 21. Traffic jam along Paseo de la República Fwy. next to the BRT lane in Central Lima. Source: Natalia Pulido (2018).

5.6. Environmental Impact

Deuman and Walsh [55] suggested that, in Lima, the highest emissions to the atmosphere produced by vehicles were: carbon dioxide (CO_2: 3,879,620 tonne/year, followed by carbon monoxide (CO: 137,891 tonne/year). Volatile organic compounds (VOC) accounted for 18,225 tonne/year, while sulphur oxides (SOx) and nitrogen oxides (NOx) emissions were estimated as 7022 tonne/year and 32,170 tonne/year, respectively. When the emissions are divided according to transport mode, transit (buses, minibuses and combis) was responsible for 42% of NOx emissions and 68% of SOx emissions, whereas private modes (cars, taxis, pick-ups and motorcycles) accounted for 91% of CO, 80% of VOC and 44% of CO_2 emissions. The spatial distribution of these emissions is homogeneous for all gases as it is concentrated in Central Lima [55], the area where all transport modes meet. Transport emissions per capita in Lima are below the levels of car-oriented cities because of the low car ownership and comparatively low use (Figure 22 [55,57,63,70]). It is important to remark that Deuman and Walsh's survey was made before the formal transit modes (BRT, Metro and Complementary Corridors) were introduced in 2010. The Metropolitano is the first system in the region to work with natural gas vehicles (NGV) and has contributed to the reduction of 26,500 tonnes annually of greenhouse gases with the removal of 790 buses that travelled along its route [71].

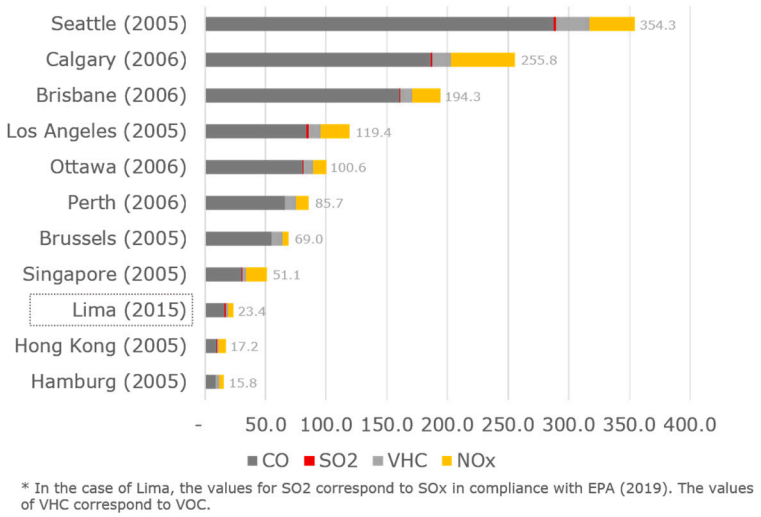

Figure 22. Total transport related emissions per capita (kg/person of CO, VHC (VOC), SO_2, and NO_X combined). Source: References [55,57,63,70]. Graph by authors, 2019.

5.7. Safety

This final indicator has the greatest impact on citizens' lives beyond time and money losses. In 2015, the National Police of Peru reported 52,489 transit accidents in the city [34], which represent 59% of the accidents countrywide [72]. Without considering Callao, 49% of the accidents occurred in Central Lima, followed by Eastern Lima (21%), Northern Lima (17%) and Southern Lima (14%) [61]. The highest number of accidents was along Javier Prado Ave. (2022), followed by Panamericana Sur Fwy. (1773) and Panamericana Norte Fwy. (1478) in the periphery [61]. There were 492 deaths in fatal transport accidents, 60% of which were caused by driver recklessness (predominantly speeding), whereas only 22% were the pedestrian's fault [34]. The district with highest fatal accidents was Callao (58), followed by Comas (46) in Northern Lima. However, the highest concentration of fatal accidents per 1000 people occurs in the peripheral districts of Southern Lima where the Panamericana Sur Fwy. runs [34]. Worldwide, Lima sits somewhere in the middle (Figure 23 [54,63] with 4.8 deaths per 100,000 people [54], though this number is likely understated as other cities are based on the WHO's ICD 10 data, which includes death in hospital 30 days after an accident, while police records are only death at the scene of an accident).

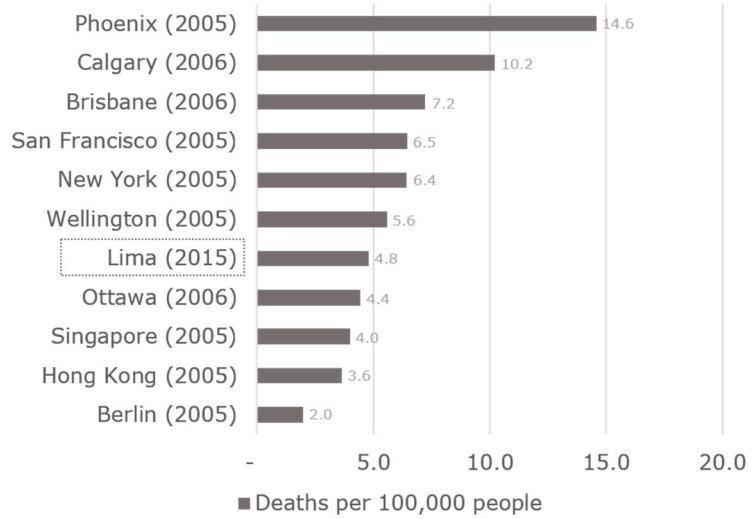

Figure 23. Total transport deaths per 100,000 people in world cities. Source: References [54,63]. Graph by authors.

6. Conclusions and Recommendations: What Might Lima Do to Strengthen Its Urban Structure and Improve Its Transport System?

From periods of political instability and economic bonanza, the City of Lima as capital of Peru and its first megacity, has been the country's motor and center of its major socio-economic and political processes as an emerging economy. The result is a city with portions of formal and non-formal areas and high rates of inequality, typical of Latin American cities. The urban agglomeration of Lima is formed by five different sectors: Central, Northern, Eastern and Southern Limas that are merged with the Province of Callao. The metropolitan region exceeds 80 km from north to south and faces issues of mobility and lack of adequate urban infrastructure. It also depends largely on a poly-centerd area located in what remains of the traditional, early city.

A lack of political commitment to proper planning has had its consequences in the way the city has been shaped. The process of non-formal expansion of Lima, along with the urbanization of the agricultural land within the city during the 20th century, the growth of the marginal neighborhoods and the urbanization of the balnearios by private initiatives during the 21st century, show a marked lack of effective and orderly governance in city planning and reflects a passive attitude by the State to improve matters.

6.1. An Informal Transit City

During the 20th century Lima saw the deterioration of its transit system. From railways and trams that connected the centre with Callao, Miraflores and Barranco, the city shifted to ENATRU buses, a predecessor of the BRT system. These systems were driven by State companies, but were not able to supply the growing population at the time. Consequently, as in many other developing cities where formal transit is insufficient, informal transit modes have appeared to cover this demand. When Fujimori came to power, his free-market policies deeply affected the evolution of transit, privatizing routes and allowing free access with any kind of motorized vehicle, while the cheap import of used vehicles, considerably increased the informal transit sector. These modes, comply with Cervero's [4] definition of informal transit: small-passenger-capacity, low-performance vehicles driven by private operators without proper credentials regarding safety and vehicle maintenance. Minibuses and combis have proliferated all over Lima and have become the dominant transit modes. These services offer short waiting periods between services, low fares, and can reach almost the entire city without the need for transferring between services, though other service qualities are low.

The long-term result, however, was much less advantageous for the city. The sheer numbers of informal transit vehicles on the streets causes traffic chaos, accidents and a range of environmental impacts. The drivers of these vehicles who live on the daily profit need to collect as many passengers as possible, and in this fierce competition, they infringe transit regulations and speed limits. Although new formal modes have appeared, such as the Metropolitano, Line 1 of the Metro and the Complementary Corridors, the effects of almost two decades without formal transit are clearly visible. There is a lack of an efficient, integrated transit system and an autonomous regulating authority.

From the global comparative data, the following can be concluded: Lima is not a walking city as foot (and bike) trips represent only 25% of daily trips, though by international standards this is still a reasonable modal split for NMM trips. The average from a large sample of world cities in 2005–6 was 24% [73]. Although the retail and shop offer is diverse and covers every sector of Lima, the extension of the city and concentration of jobs and services in Central Lima demands trips far from peoples' areas of residence, often exceeding 16 km.

Lima, however, is also not an automobile-oriented city because of the low car ownership primarily concentrated once again in Central Lima (but also with significant numbers in the balnearios and suburbs of Eastern Lima). Additionally, per capita freeway availability is low in comparison with traditional car-oriented fabrics and do not represent a network for effective and free movement of automobiles, since freeway lengths are short and disconnected from one another. Along with their bypasses, located within intersections with traffic lights, they do not solve Lima's traffic problems.

Private vehicle ownership also covers the strong presence of mototaxis as paratransit modes located on the periphery. Unlike private car usage, these vehicles are used for local trips and represent the only mode of motorized transport in areas where transit cannot reach.

Finally, it also cannot be assumed (yet) that Lima is a transit city, especially due to the low length of exclusive lanes for transit, (currently only 60 km). This positions Lima at the bottom of the compared cities on this factor. Moreover, there are only two formal mass transit modes (BRT and Line 1 of Metro) that together cover less than 2% of the daily trips. Both conditions reveal the low investment from the city's administration in transit and the lack of interest in improving the quality of life of citizens. However, the usage of other public modes is strong. In total, transit represents almost 50% of daily trips in Lima. From this amount, more than 90% of transit demand belongs to informal combis, buses and minibuses. Furthermore, this reliance on transit is similar in the five sectors of Lima. From these results, one can conclude that at present Lima is an informal transit city.

How long this remains this way is questionable. As expectations and incomes rise, informal transit systems, offering a relatively low quality of service, albeit cheap, are frequently the first modal split casualties, as people shift to motorcycles and then cars, in the absence of improvements in transit.

6.2. Towards a Better Transit City

It can be said, however, perhaps optimistically, that Metropolitan Lima has three main attributes that can potentially help shift the city's transit system towards a more sustainable one. First, car ownership is still relatively low which can help a transition to a more formal transit model, setting good transit habits before car-oriented ones set in. Unlike car-oriented cities, that still need to reduce their car ownership levels and peoples' car-oriented habits, Lima today only has 132 cars per 1000 persons (although their impact is disproportionately high in a city not originally designed for the current car flow and where job offer is concentrated in the traditional centers). On the other hand, paratransit private modes have local relevance rather than a metropolitan impact. They are part of the solution that presently connects citizens of non-formal neighborhoods with mass transit (BRT and Metro).

Secondly, although the metropolitan region continues spreading in northerly and southerly directions, the average urban density of 136 people/hectare is more than adequate for very high transit use (and indeed more non-motorized mode use if there was policy and practical attention to improving conditions for pedestrians and cyclists). Unlike other cities, this density is not concentrated only in the center: Densities in Lima Conurbana can vary between 150 and 200 people/hectare (Table 3 [13]), where most population of the urban region lives.

The final and most important attribute is that Lima is already a transit-oriented city, though the transit is mostly not of high quality. Transit will remain threatened by increasing car and motorcycle ownership if nothing is done to limit this growth and improve transit's standards and competitiveness, in line with rising expectations in Lima. The preference for, or at least captive use of transit, is to some degree homogeneous in the whole region. This can support efforts in shifting from informal transit towards the establishment of formal modes, such as the expansion of the Metropolitano BRT and the future metro network.

Singapore in the 1960s had some features akin to Lima today (dense city, low but growing GDP, congestion, bus-only transit, increasing private transport, etc.). Through somewhat less than democratic, though highly effective means (it has at times been labelled a "benevolent dictatorship"), it pursued a coordinated vision based around a metro system, dense, integrated mixed land uses around stations and traffic limitation strategies and became a transit metropolis [74,75]. Townsend [76] outlines some of the detailed political and bureaucratic means by which Singapore achieved its planning and transport successes.

6.3. Recommendations

Given Lima's still heavy reliance on informal transit, it is necessary to put more emphasis on transport reform. The current neoliberal transit model, in which transit companies rent their granted

routes to third parties, who at the same time sub-rent their vehicles to drivers who live on daily income, is not sustainable in the long term. The still delayed Authority for Urban Transport (ATU) represents a promising opportunity to reform transit governance and take control of the different transport modes that so far are divided by the Municipality of Lima, the Municipality of Callao and the Ministry of Transport and Communications (MTC). This could facilitate an efficient, integrated transit system with inter-modal travel tickets suitable for all modes. Perhaps the most successful governance arrangement for transit is that of the Verkehrsverbund in Zurich, Vienna, and major German cities (e.g., Munich, Berlin, Frankfurt), with large increases in quality transit services, higher investment and much better use of transit since their implementation. A Verkehrsverbund or "transport community" provides a way of managing and coordinating all transit services in a region [6]. Lima might learn from such arrangements in reforming its transit governance.

It will be necessary that this Authority address the high social cost that a transport reform implies, due to the large number of people who work in the informal transit sector without proper employment benefits. Furthermore, the introduction of solid policies against corruption are essential to avoid collusion and corruption cases between authorities, transport companies and contractors for infrastructure supply (as occurred during the construction of the BRT line). Transport policy and investment priorities need to reflect the fact that transit and non-motorized modes constitute 74% of daily trips. Municipal budgets should be invested in far more space-efficient transit, walking and cycling, rather than in freeways and bypasses. The high VKT per capita of service by large numbers of informal transit vehicles is reflective of the vast numbers of low capacity transit vehicles, which need to be rationalized and partially replaced by higher capacity, more attractive formal transit.

Perhaps it is time to examine Lima's transport history and the trams that were used during the first half of the 20th century. Such systems are still very common in European cities and have been successfully adapted in numerous North American cities. The return of an updated light rail transit system (LRT) could help accommodate the high travel demand on major corridors without the current saturation service of low capacity vehicles. However, with the densities that predominate in Lima, a successful LRT system may also become quickly saturated with demand. It is thus very important when considering formal modes of transit in Lima, to carefully choose the mode that is best fitted for prospective demand. In many cases metro systems running multiple wagons may be the only future-proof solution along some corridors. In other less dense areas, LRT or BRT may well be best suited to demand. Metros are of course very expensive but their costs can be ameliorated to some extent by building above ground on viaducts which can allow for good urban design solutions under the elevated structures, such as the multi-use pathways for walking, cycling and gardening under SkyTrain guideways in Vancouver [77]. These strategies could also be applied to the current above-ground Line 1 of Metro.

Additionally, Lima's weather and topographic conditions represent a huge advantage to encourage bicycle use as an alternative towards a more sustainable model. Investment should be directed to provide adequate bicycle-friendly infrastructure and strategies that prioritise pedestrians and bicycle users as Bogota has done [78]. Mototaxis in the periphery of Lima should also be considered in the new transit model as they are used for local trips in sloped areas where other modes cannot reach and as part of the inter-modal split with the Metropolitano and Line 1 of Metro. Their integration with formal transit modes is also a way to think of a more egalitarian city in which everybody has access to proper transit. This could be enhanced through, quieter, less polluting, and safer solar-powered vehicles. Aerial Ropeway Transit (cable cars) may also be an option in heavily sloped areas of Lima, as in Medellin in Colombia [79].

Finally, the mobility and city structure analyses in this paper suggest that a decentralized, polycentric model needs to be more effectively implemented to reinforce local centralities and make employment available in accessible nodes away from the traditional centers. In this way, travel times around Lima will be more equal, reducing the need to spend more than two hours a day travelling.

To achieve this, however, the role of efficient public administration, good governance, and political leadership is vital.

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