METRO SYSTEMS IN LATIN AMERICA, COMPARISON OF PLANNING AND DEVELOPMENT MODELS VERSUS OTHER REGIONS IN THE WORLD

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ABSTRACT

The population growth in cities pushes to seek solutions for the mobility of people, one of the most efficient but at the same time more expensive solution is a rapid transport system, commonly known as metro systems. In last 50 years, Latin America has seen how many of its cities have grown to have populations of several million inhabitants and therefore they have considered the development of a first metro line or if they already had existing lines, expand the metro network. This study seeks to understand the planning and development models of metros in Latin America and analyze the traits of these systems, compared to metros in other regions of the world. The conclusions of this study will not only be useful for local planners, but also for development banks and other international organizations in a way that they can understand and adapt their processes to local conditions. The research uses statistical information from benchmarking groups of metro systems throughout the world, as well as information presented in annual reports of companies operating metro systems. Academic documents are also used, as well as reviews and analytical studies by experts from international organizations and multilateral banks. In the first section of the paper, planning models to develop a metro project are analyzed, then a comparison is made between levels of demand or passenger flows and economic-financial variables and finally the operation models are studied. Conclusions are presented with the most relevant factors to consider when planning and developing a metro system in Latin America.

1. INTRODUCTION

1.1 The Latin American context: the demographic explosion and the construction of metro systems

During the last century and a half, the Latin American region has experienced explosive demographic growth, going from a population of 75 million in 1900 to 165 million inhabitants by 1950, continuing growing to 510 million inhabitants by 2000 and it is estimated that in 2025, the population will reach 783 million inhabitants (Ortiz Álvarez et al., 2003), this means an increase of more than 1000% in the period stated. But not only the population grew, but it has also become more urban, going from an urbanization level of 25% in 1925 to a percentage of urban population of 75,3% in 2000, and its projected urban population will reach 82,2% in2025, also being the region of the planet with the greatest changes in population growth and levels of urbanization (Lattes, 2001). As for the most

populous cities in Latin America in 1900, none exceeded the figure of one million inhabitants, by 1950 six cities in the region had exceeded one million inhabitants, and by 1995 39 cities within the region had exceeded that population, including three cities that had more than ten million inhabitants (Ortiz Álvarez et al., 2003).

At a global level, the phenomena of population growth and urbanization have led to public transport having a substantial weight in the dynamics of large cities and urban metropolitan railways, commonly called “metros” which are among the most implemented solutions in large cities. Studies cite that the 10 largest metro systems in the world transported more than 22,000 million passengers in 2013, equivalent to three times the world population (Brage-Ardao et al., 2015). In Latin America the trend towards the construction of metro systems has not been different from the rest of the world. Throughout the 20th century, metros had been built in thirteen cities in Latin America, but in just two decades of the new millennium ten new cities in the region joined the club of cities that have metro systems (Clemente, 2013).

1.2 The particularities of Latin America in transportation investments

Latin America is in a construction boom of metro systems, but this region has its own conditions that are not necessarily similar to other regions of the world where many metro systems have been built, such as in Europe, North America, and Asia.

Latin America is a developing region, with a series of social challenges, including considerable levels of poverty, political instability in its governments, and difficulties in state finances that lead to limitations on public investment. The region has been involved in successive financial crises, which has influenced the capacity of state or local governments to make investments, which has been reflected in the fact that it is the region of the planet with the lowest level of investment in infrastructure, just 1.8 % of GDP, which has led it in recent years to focus on different types of concessions or public-private participation (PPP) (Vassallo Magro, 2015). It is essential to study the planning and management models of transport infrastructures in the region, addressed in section number two of this document. Although the population's transportation needs are high since the region is very populous and with high levels of urban concentration in large cities; on the other hand, the aforementioned financial limitations at the level of investment in infrastructure lead to unique phenomena in terms of demand levels and use of metro systems in the region. These phenomena will be explored later in a comparison by regions. Finally, the permanent tension due to financial issues in the region prompts a search for financing sources of various origins and that many metro systems in the region have a vocation for financial self-sustainability.

Given the nature of this research, the main method of gathering information will be by bibliographic sources, including scientific articles, reports from operators or concessionaires of metro lines, comparative reports from benchmark associations of comparative analysis and by studies, reports and reports of multilateral development and investment banking

2. LITERATURE REVIEW

Due to their nature of large-scale works, metro systems have been inserted in urban spaces and with constructions that require underground works or viaducts, present construction complexities and high investment costs. According to an analysis of 40 metro lines in the world, their construction costs range from US $ 50 million to US $ 150 million per kilometer of construction (Flyvbjerg et al., 2008), and a study by the same author shows that the presence of cost overruns are on average 45% above the original budget (Flyvbjerg, 2007). Other authors have studied the causes of cost overruns, finding in 75% of the cases incomplete or low-quality designs, work delays and administrative problems between the parties involved (Cantarelli et al., 2010). The problems in the metro systems do not end with their construction, since their operation also involves great challenges, both in terms of demand coverage and financial sustainability. Flyvbjerg reports that worldwide 9 out of 10 projects do not meet expectations for passenger demand ranges, with three-quarters of those projects falling below 40% of forecast demand (Flyvbjerg, 2007); moreover metro projects are the most inaccurate at the level of demand forecasts in the field of transport, which has been maintained for several decades (Siemiatycki & Friedman, 2012). Lastly, financial sustainability is a critical factor in metro systems worldwide, and it is thus that in benchmark reports comparing metro systems in various continents, very few operators achieve a degree of cost coverage equal to operating revenues, commonly called the “coverage index” (ALAMYS, 2013; Condry, 2013). This inability to achieve financial equilibrium at cost level and operating income indeed leads metro operators to demand high levels of subsidies from central or regional governments. Given the fact of presence of various levels of risks in terms of: design, construction, demand forecast, and political, some mechanisms have been found at international level in order to transfer this risks to private parties, under various administrative modalities of operation contracts, concessions and public-private participations (PPP) that allow transferring the risk from the infrastructure developer to the private sector (Siemiatycki & Friedman, 2012), existing a diverse variety of models ranging from the traditional model where the project developer is responsible for all phases, to complex and varied alternatives where one or more phases of the Design (D), Build (B), Operate (O), Finance (F) stages are transferred to the private party and - if applicable - the Transfer (T) or Property (O) of the project. Hence, progressive models of involvement of the private sector as a concessionaire are described. Each acronym described represents the commitment that the private sector acquires in the PPP such as: DB, DBO, BOT, BOO, until reaching the broader risk transference model the DBFOT, also called “turn key”, here, the project developer leaves everything in the hands of the private company that takes action in all activities from design, through construction, to long-term operation (Clemente, 2013; Delmon, 2010; Wojewnik- Filipkowska, 2012).

There are other factors that influence metro systems, beyond the development models of the projects. On the one hand, studies show that there are particularities or conditions both in favor and against for those "greenfield" type projects that correspond to absolutely new

infrastructures for the environments where they are implanted, compared to "brownfield" type projects, which are those that are an extension or are very similar to an existing project (Amos, 2004; Gago De Santos, 2014) and the literature consulted agrees that among the advantages of greenfield projects are the high degrees of freedom to start a project without previous conditioning factors, meanwhile among the disadvantages is the lack of experience in these projects. And finally, another major issue that influences metro projects is the approach to receive technical support and financing from multilateral entities ,or development banks compared to new technical and financial parties such as Asian governments. In this sense, multilateral financial entities not only act as lending banks, but there is also a strong focus on developing internal capacity of project operators by improving institutional capacities and technical and knowledge transfer (Sagasti & Prada, 2002). Faced with this alternative, in the last two decades, there has been a strong influence of new actors such as the case of China, a new infrastructure lender in the region (Gallagher et al., 2013; Slipak, 2014), although these credits are linked to obligations to contract Chinese companies and under the conditions that their government requires, according to Gallagher and Slipak.

3. COMPARISON OF LATIN AMERICA METROS VS. OTHER REGIONS OF THE PLANET

Obtaining data from all metro systems in the world is an extremely complex task, not only due to the high number of existing metro systems, which by 2018 were 182 cities (UITP, 2018), but also because many of those systems do not carry complete statistics on their operations; moreover, even if they have statistics, they do not have standardized indicators that allow comparisons between equivalent parameters. Therefore, in order to be able to compare Latin America’s metro systems with metros in other regions of the world, the data and information have been taken from some metro systems that are representative of each region and for which there are sufficient data and harmonics with one another. The information come from public use of benchmarking metro associations such as reports from the Asociación Latinoamericana de Metros y Subterráneos (Latin American Association of Metros and Subways) (ALAMYS, 2014), Community of Metros Benchmarking Group (Anderson, 2006; Anderson, Findlay and Allport, 2010; Condry, 2013) and the Union Internationale des Transports Publics (UITP, 2012, 2016, 2018) as well as annual reports or official reports from metro operators (Azienda Trasporti Milanesi, 2015; Taipei Rapid Transit Corporation, 2015; Transport for London, 2015; CRTM, 2015; Delhi Metro Rail Corporation Ltd., 2015; Metro Sao Paulo, 2015; Metropolitan Transportation Authority - MTA, 2015; MTR, 2015; SMRT, 2015; BVG, 2016; Washington Metropolitan Area Transit Authority, 2016; San Francisco Bay Area Rapid Transit, 2016; Metro Rio, 2017) and of multilateral entities or investment and development banks from consultants or analysts of these institutions (Rebelo, 2006; Mitric, 2013; Ardila-Gomez and Ortegon-Sanchez, 2015; World Bank et al., 2015; European PPP Expertise Center, 2016; Pulido, 2016; Pulido et al., 2018)

3.1 Demand level versus the size of the metro network

The first feature which has been found particularity in metro systems in Latin America compared to other regions, is the high demand they have in relation to the size of those metro networks. To carry out the analysis, it is necessary to compare the variables "number of annual travelers" expressed in millions of passengers (MMpax) with "network size" expressed in kilometers. Some metro systems have been selected from each region among the most representative operations. These data are observed in table 1, and in graph 1.

City - Operator	Region	Network Length (km)	Annual passengers (MMPax)	Passengers by Network Length (MMPax/km)
New York City Subway	North America	485	1751	3,61
Washington Metro	North America	171	209	1,22
Montreal Metro	North America	71	280	3,94
San Francisco BART	North America	197	128	0,65
Average metros selected North America		**231**	**592**	**2,56**
London Underground	Europe	402	1265	3,15
Metro de Madrid	Europe	294	561	1,91
Berlin U-Bahn	Europe	175	500	2,86
Metro de Milan	Europe	97	350	3,61
Metro de Valencia	Europe	147	60	0,41
Average metros selected Europe		**223**	**547**	**2,45**
Hong Kong MTR	Asia	185	1578	8,53
Shanghai Metro	Asia	613	2500	4,08
Singapore MRT	Asia	142	1200	8,45
Delhi Metro	Asia	212	780	3,68
Taipei Metro	Asia	129	680	5,27
Average metros selected Asia		**256**	**1348**	**5,26**
Mexico City Metro	Latin America	200	1580	7,90
Metro Sao Paulo	Latin America	75	800	10,67
Metro de Santiago	Latin America	105	650	6,19
Subte de Buenos Aires	Latin America	45	380	8,44
Metro Rio	Latin America	45	200	4,44
Metro de Medellín	Latin America	35	201	5,74
Average metros selected Latin America		**84**	**635**	**7,55**

Table 1: Passengers by Network Length (MMPax/km)

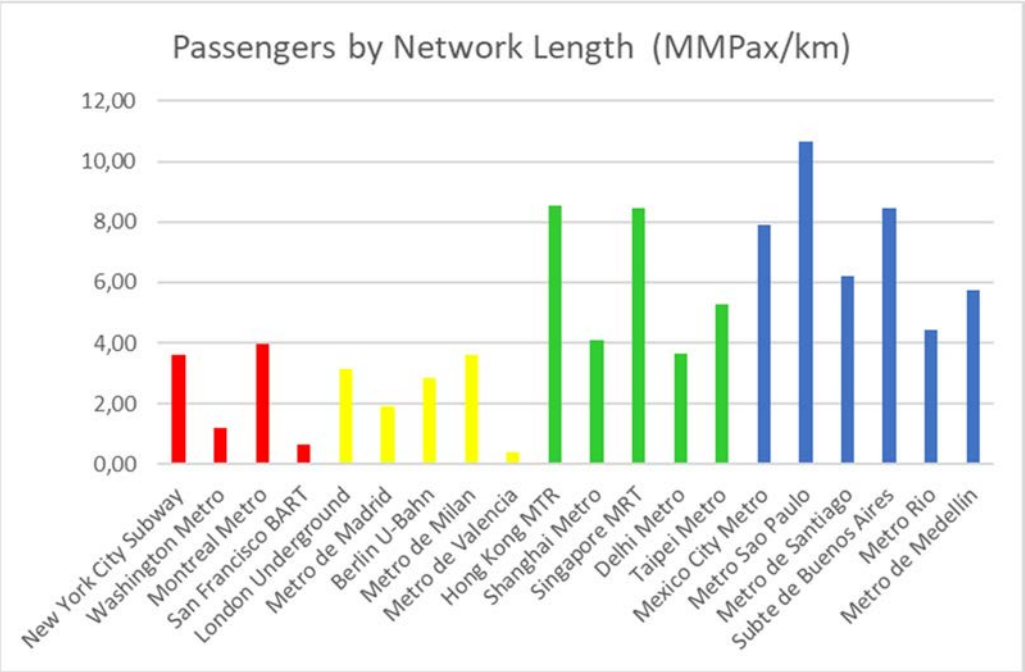

Figure 1: Passengers by Network Length (MMPax/km)

The calculation of the average of the selected metro systems shows that the metro systems in both Latin America (7.55 MMpax / km) and Asia (5.26 MMPax / km) have higher levels of demand for the lengths of the metro networks than their counterparts in North America (2.56 MM / km) and Europe (2.45 MM / km). Actually, passenger load per km in Latin America is the highest in the world.

3.2 Financial Sustainability

In order to evaluate this parameter, two variables will be analyzed; on the one hand, the quotient called "recovery ratio" which represents a relationship between operating income versus operating costs, in such a way that a recovery ratio greater than 1 represents that all the operating costs are paid with operating income received and therefore the operation of the metro system is financially sustainable, and a ratio lower than 1 represents that the operation does not cover its costs and will permanently need government subsidies. The second variable used is “additional or non-tariff income”, which corresponds to all commercial activities that are not related to transport activities but generate income in a metro system. Among these are commercial advertising in stations or on trains, businesses related to telecommunications within the metro network including mobile telephony, the rental of store places within metro stations and even activities outside the metro system like real estate activities related to administration of residential buildings and shopping centers in areas near metro stations. The comparative data of the two mentioned variables can be seen in Table 2.

City - Operator	Region	Recovery Ratio	Percentage of revenues not related to transport
New York City Subway	North America	50,3%	7,3%
Washington Metro	North America	36,5%	5,0%
Montreal Metro	North America	64,0%	6,0%
San Francisco BART	North America	67,0%	9,9%
Average metros selected North America		**54,5%**	**7,1%**
London Underground	Europe	100,6%	16,0%
Metro de Madrid	Europe	73,9%	6,2%
Berlin U-Bahn	Europe	57,6%	12,9%
Metro de Milan	Europe	91,9%	8,6%
Metro de Valencia	Europe	52,5%	4,2%
Average metros selected Europe		**75,3%**	**9,6%**
Hong Kong MTR	Asia	183,8%	29,3%
Singapore MRT	Asia	128,1%	26,8%
Delhi Metro	Asia	149,7%	7,7%
Taipei Metro	Asia	118,5%	16,1%
Average metros selected Asia		**145,0%**	**17,9%**
Mexico City Metro	Latin America	41,7%	4,6%
Metro Sao Paulo	Latin America	102,7%	11,5%
Metro de Santiago	Latin America	103,3%	19,8%
Metro Rio	Latin America	170,9%	8,1%
Metro de Medellín	Latin America	153,1%	5,4%
Average metros selected Latin America		**114,3%**	**9,9%**

Table 2: Recovery ratio and Percentage of revenues not related to transport

It is notable that in terms of the recovery ratio, very few operations in Europe and North America manage to cover all their costs with operating income, while in the case of the metro systems in Asia and Latin America, several of them exceed the recovery ratio of 100%. In fact, when evaluating all the systems in Latin America and Europe, there are 5 metro systems that are financially self-sustainable and a similar number that approach recovery ratios equal to or greater than 100% in Latin America, whereas in Europe there is only one metro with a ratio of recovery greater than 100%. By comparing averages of the recovery ratio for the metro systems selected, it is observed that Asia has a recovery ratio of 145% and Latin America 114.3%, while Europe has 75.3% and North America 54.5%.

A similar situation occurs with incomes that does not come from transport activities, and looking to the average of the metros selected, it is noticeable that the Asian metro systems lead in obtaining this type of non-tariff income with a 17,9% average of in revenues not related to transport, followed by the metro systems of Latin America (9.9%) and Europe (9.6%), and at a greater distance those of North America (7.1%).

Considering the two variables, it can be concluded that in Asia and Latin America there is a strong effort to obtain financial sustainability, while in North America and Europe there is no high interest in achieving it. This goes hand in hand with the social perspective existing in most European countries, where transport systems are a service and a fundamental citizens' right.

3.3 Greenfield projects, degrees of freedom and technical experience

As mentioned above, there are brownfield-type metro projects that are extensions of previous projects (such as a new metro line in an existing system or the extension of a line) and greenfield-type projects where there are no pre-existing metro lines in the same city or even in many cases, within the same country. Greenfield projects have advantages and disadvantages. One of the advantages is the possibility of working with a greater degree of freedom, since there are no conditions for following the standards of previous or existing metro lines that force the use of technical specifications such as platform size, voltage levels, train width, among others; which for the project developer and the builders is favorable since it allows greater freedom for the designs and construction. In contrast, the biggest disadvantage of a greenfield project is that there is no prior technical experience; therefore, there are no local engineers knowledgeable about these systems and acquiring that experience has considerable costs.

In Latin America, with the exception of Brazil, which has several metro systems and extensive metro construction experience, for the rest of the countries the metro systems development processes have fallen into the typology of greenfield projects, and for their developers this has demanded strong learning and costs associated with this need to learn and to acquire urban rail technology. Statistics show that in eight Latin American countries there is only one city that has a metro system: Argentina, Colombia, Chile, Ecuador, Panama, Peru, Puerto Rico and the Dominican Republic (Clemente, 2013). In other words, for those eight countries, the metro systems have been greenfield projects. And even more, given the low regional integration of Latin America, the developments of new metro systems in other countries of this region will also fall into the greenfield typology, unlike Europe or North America where there is high regional integration and railway experts can relocate labor very easily from one country to another.

3.4 Public Operation and Public-Private Participations

Several studies confirm that unlike in Europe, Asia and North America, where Public-Private Partnerships (PPP) are frequently used in the operations of metro systems, in Latin America PPPs have not been used frequently, or instead, these concessional models are fairly recent or appear as a result of a continuity crisis due to poor performance (Leipziger and Lefevre, no date; Schwartz, Corbacho and Funke, 2008; Chang, 2013; Carpintero and Helby Petersen, 2014; Gago De Santos, 2014; World Bank, 2014).

In Latin America, there are currently PPPs in Brazil in the cities of São Paulo and Rio de Janeiro; Argentina in the city of Buenos Aires (Rebelo, 2006), and Lima in Peru (Ositran, 2017), all these PPPs have appropriate financial and operational results for cities and their users, according to the sources cited above. But besides these mentioned cases, in the rest of the 22 metro systems in the region, the operation by themselves is imposed at the level of public sector equity companies. Furthermore, in the case of Rio de Janeiro and Buenos Aires, these concessions are from recent times and in the case of São Paulo, they only correspond to one line of the entire system. This shows that despite PPP models attempts have been introduced in the region, they still do not have strong acceptance by local or national governments that are the owners of the metro systems.

4. CONCLUSIONS

The comparisons that have been presented allow us to find some particular characteristics of the metro systems in Latin America in terms of high levels of passenger demand, a permanent concern for the financial sustainability of metro operations, the preeminence of greenfield type projects in the region and, finally the little acceptance that PPPs have had in the region's metro systems.

Understanding the particularities of the metro systems in the region and making good use of this information will be very useful for transport planners, development bank executives, railway constructors, metro operators and finally for politicians and policy makers in general, who will be able to better adapt their vision on how metro lines are developed and built in Latin America.

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