

# Determinants of Rapid Transit Planning Processes in Ecuador

by

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This thesis consists of material all of which I authored or co-authored: see Statement of Contributions included in the thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

## Statement of Contributions

This thesis includes materials from journal publications and one manuscript under review as listed below. In all the enlisted publications Juan Arias was the primary researcher and author, supervised by Professor Chris Bachmann.

Arias, JF., & Bachmann, C. (2019). Analysis of private participation effects in bus rapid transit projects in Ecuador. *Transportation Research Record: Journal of the Transportation Research Board*, 2673 (1), 503-513. <https://doi.org/10.1177/0361198118823005>

- Chapters 1, 2, 3, 6 and 7

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## **Abstract**

This research presents a novel framework for the quantitative and qualitative analysis of rapid transit planning processes based on a mixed-method approach, along with the corresponding results: the relative importance of factors that affect the projects, a ranking of the critical barriers that hinder their implementations, and the implications of private participation. The planning and implementation of rapid transit in Ecuador has proven to be a daunting endeavor. Nineteen projects have been planned, but only nine have reached implementation. This research seeks to understand how these projects' design and implementation processes were shaped.

The analysis of the design process focuses on how different factors (demand, local conditions, financial, social and political) have influenced all of the rapid transit projects in Ecuador over the past three decades by evaluating their relative significance on each system component (alignment, size, and technology). This analysis uses a multiple-case methodology including in-depth interviews with the senior members of the technical teams, as well as a survey component based on the Analytic Hierarchy Process (AHP) for quantification of the relative significance of the factors.

The analysis shows five key results: 1) Each project was unique and external factors introduced a varying degree of complexity into each planning process; 2) The systems' alignments and sizes were mostly driven by demand and local conditions (i.e., a rational planning process); 3) The main factor driving technology selection has evolved over time from system demand to political (i.e., a political bargaining approach); 4) Negative economic conditions had a large influence on the factors of all project components; and 5) There is a lack of rational alternative evaluation and an absence of corresponding tools/guidelines in Ecuador. Nonetheless, several processes included practices that contributed to a more rational planning process: lifecycle cost analysis for the various technology alternatives, explicit decision-maker guidelines, transferring the demand risk to the private sector, and the use of Multicriteria Decision Analysis (MCDA).

In terms of project implementation, this research evaluates the critical barriers for project implementation along with corresponding mitigation measures. A mixed-method, based on an existing theoretical framework and Best-Worst Scaling (BWS), is proposed and applied. The

analysis is grounded by in-depth interviews and surveys conducted with the technical teams of the planned projects. Results show the top tier of the critical barriers is composed of 1) Lack of political leadership, commitment or continuity; 2) Underestimation of implementation complexities; 3) Political frictions; and 4) Rushed planning processes. Seven key mitigation measures were identified and linked to each barrier: 1) Connect the social, political and technical perspectives; 2) Aim at starting construction before the end of political cycles; 3) Increase the private role in the procurement strategy; 4) Increase community input during planning; 5) Generate public opinion monitoring; 6) Adapt projects features to community input (when applicable); and 7) Focus on the implementation of one trunkline at a time. Moreover, evidence suggests critical barriers are not technology specific, but rather endemic to the planning process and that the projects' critical political dependence promoted planning based on political cycles in detriment of long-term efforts. These findings align with previous results from developing cities, confirming the transferability of results at an aggregate level, but also show that the barriers and corresponding mitigation measures can be context specific.

In both, the design and implementation stages, the private participation led to different outcomes. The two largest cities in Ecuador each implemented three BRT corridors (1995 to 2013). The projects present similar characteristics, and thus a unique opportunity to analyze how private participation influenced their performance. The analysis identifies the level of private participation and to what extent it influenced the outcomes of the projects. Two approaches were identified: 1) Including incumbent operators by delegating vehicle acquisitions and operations; and 2) Replacing them with a public company. Financial strength and interest of the incumbent operators to continue functioning along parallel routes were major issues. Quito was successful in the implementation of the first corridor through public delivery, but failed its attempts with private participation. Guayaquil surmounted the barriers for effective private participation through a Special Purpose Vehicle (SPV) that managed the risk due to the inherent nature of the consortiums.

This research provides the first comprehensive analysis of the design and implementation processes in Ecuador. It is expected that the results will contribute to more efficient and sustainable investments in the future.

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My deepest gratitude goes to Prof. Chris Bachmann whose guidance and insights were invaluable to complete this research. Chris not only reviewed, patiently, hundreds of pages and provided detailed comments that improved the quality and clarity of each subsequent draft, but dedicated countless hours to discuss and review the research in person. I will deeply miss these reflective conversations.

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## List of Abbreviations

AHP	Analytic Hierarchy Process
BATS	Bay Area Transportation Plan
BRT	Bus Rapid Transit
BWS	Best-Worst Scaling
CATS	Chicago Area Transportation Plan
CN	Central Norte BRT corridor
D	Demand
DBB	Design Bid Build
DBBMP	Design, Bid, Build, Multi-prime
DBFOM	Design Build Finance Operate Maintain
DBFO	Design, Build, Finance, Operate
EPMTP	Empresa Publica Metropolitana de Transporte Público
FF	Financial Factors
GDP	Gross Domestic Product
LC	Local Conditions
LRT	Light Rail Transit
MCDA	Multi-Criteria Decision Analysis
PATS	Pittsburg Area Transportation Plan
PDE	Planning Design and Engineering
PDM	Project Delivery Method
PF	Political Factors
PPP	Public Private Partnership
RoW	Right of Way
SF	Social Factors
SHRP	Second Strategic Highway Research Program
SPV	Special Purpose Vehicle
TCRP	Transit Cooperative Research Program
TRB	Transportation Research Board

## List of Publications

The following publications correspond the research contained in this thesis.

- Arias, JF., & Bachmann, C. (2019). Analysis of private participation effects in bus rapid transit projects in Ecuador. *Transportation Research Record: Journal of the Transportation Research Board*, 2673 (1), 503-513.  
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# Chapter 1

## Introduction

### 1.1 Background

Rapid transit has become a crucial component of urban areas. The roots of their planning processes can be traced back to the 1950's in North America, where rapid transit was evaluated as part of the Chicago Area Transportation Plan (Black, 1990). Earlier planning efforts focused on highways and sought to optimize level of service measures (e.g., speed and travel time) (Meyer & Miller, 2001; Vuchic, 2005), but in time, accessibility and transit gained importance (Buchanan, 1964). Amid this evolution, there remained a central premise of a rational planning process, well grounded in earlier traditions. However, the characteristics and nature of rapid transit projects make them particularly susceptible to external influences (e.g., social, political) and to different barriers for their implementation.

The inherent conditions of developing cities amplify these external influences (e.g., low financial capabilities, social conflicts), but also the need for rapid transit, especially considering the accelerated urban growth and large transit demand (Dimitriou & Gakenheimer, 2011; Lindau, Hidalgo, & Facchini, 2010). From 1950 to 2000, developing cities contributed to 70% of urban growth (1,974 million), while the world's urban population quadrupled (from 733 to 2,857 million) (Cohen, 2006). This rapid urbanization simultaneously promoted motorization and increased transit demand. In Quito, Ecuador, 73% of trips are completed by transit (Empresa Metro de Quito, 2012), while at the same time growth in vehicle registration from 2000 to 2019 was 78% (from 140 vehicles per 1,000 inhabitants to 250 in 2019) (Narvaez, 2014).

For Latin America, the trends observed in recent years in terms of accessibility, congestion, pollution and other externalities show a decrease in quality of life; the forecasts for the near future remain grim. The Inter-American Development Bank (IADB) has labeled this prospect as “dark times”. Moreover, ten of the world's most congested cities are in Latin America and it is expected that in the next ten years, population will increase by 11.3%, car ownership by 40%, and CO2 emissions by 25%; as well as the loss of one million lives due to traffic accidents (Roa, 2020). Additionally, the COVID-19 pandemic has had negative effects on transit (e.g., service disruptions, diminished capacities, lack of trust) and highlighted the importance of resilient rapid transit systems. Further complexities of these contexts include declining transportation access for



lesser income population, inadequate quantity and structure of road infrastructure, poorly developed municipal, fiscal and regulatory institutions, weak traffic management and high spatial concentration of population and income, among others (Gwilliam, 2003). As such, the planning and implementation processes of urban transit systems require particular approaches and contextualization for Latin America (Dimitriou & Gakenheimer, 2011; Gwilliam, 2002).

Public transit projects are of special importance for Ecuadorian cities, in part because of the massive financial burden they represent to the municipal budgets. This predicament derives from low revenue and high expenses. Consider two major cities in Ecuador: Quito and Guayaquil's (2.9M inhabitants each) municipal budgets have reached approximately 0.9 and 0.7 billion USD, respectively. Developed cities of similar size dwarf these figures (e.g., Toronto or Chicago with 2.7M inhabitants each, reach annual budgets close to 10 billion USD). On the national scale, Quito's most recent project, the first Subway Line (Line 1), represents over 2% of Ecuador's GDP. On a relative financial scale, that would be equivalent to Toronto spending 3.2 trillion dollars to implement a transit project. On the expenses side, there are larger requirements for basic infrastructure. These cities are still working to provide acceptable coverage for potable water, sanitary infrastructure and basic roads. However, even with this burden, public transportation projects have taken the center stage in municipal and even national budgets. These figures provide a glimpse of the transportation challenges and hence the importance of a well-tailored rapid transit planning process in developing countries.

In Ecuador there are eight rapid transit projects in operation (6 BRTs, 1 LRT and 1 gondola) in three cities (Quito, Guayaquil and Cuenca). Inspired by the development of the BRT systems in Curitiba (Dario Hidalgo & Carrigan, 2010), Quito pioneered their implementation in Ecuador with three BRTs, "Trolebus", "Ecovia", and "Central Norte" (CN) corridors, and Guayaquil followed with another three BRTs, "Metrovia T1, T3 and T2". These projects brought not only an improved rapid transit service, but a new organization of the urban transport sector including a new regulatory framework, formalization of operators, and the creation of new transit authorities, among other components. More recently, projects in Ecuador have begun implementing alternative rapid transit systems, similar to those in developed countries (e.g., rail infrastructure). While the roots of these projects lie in the planning processes and the factors that shaped them, the reasons for deviating from the cost-effective and high-capacity BRT systems remain unclear, as well as the reasons behind the archive (i.e., non-implementation) of nine other rapid transit projects.

## 1.2 Problem Statement

Cities in Ecuador are experiencing unprecedented population growth, increased densities, modal shift towards private transportation and the saturation of the existing rapid transit systems. As a result, the focus of municipal budgets has shifted to new rapid transit endeavors. The sustainability of the transportation system and the municipal objectives of serving the continuously increasing demand and reversing the trend of modal shift toward passenger vehicles depends largely on the successful implementation of rapid transit systems.

The planning and implementation of successful rapid transit projects in Ecuador is crucial amidst scarce financial resources and competing needs for other basic infrastructure. Projects should strive to achieve the best possible outcomes (e.g., level of service, ridership, etc.) with minimum resources. Thus, the processes should include a thorough analysis of alternatives (e.g., life cycle cost analysis of all feasible alternatives), community input and public accountability, among other elements, in order to deliver services that comply with minimum standards for the users and stakeholders, while at the same time maintaining acceptable costs. The ramifications of projects that fail to use scarce resources efficiently are detrimental for the implementation of new infrastructure and services in developing cities. It can be argued that the inefficient use of resources in developing cities increases the gap with developed counterparts, as each investment includes a larger proportion of inefficient or counterproductive resources. Conversely, successful rapid transit projects improve the quality of life and liberate much needed resources for other basic infrastructure. The dilemma of an efficient use of resources in the transport field is not new, as the seminal work of Wellington (1887) focused on the problem of whether or not to build a railway as a function of its demand (i.e., income) and costs, and the difficulties in the accurate evaluation of the projects (e.g., potential alignments). As such, transportation planning differs from other engineering fields, since the demand is directly related to human behavior and socioeconomic factors. In Ecuador, the implementation of rapid transit has proven difficult. Approximately 50% of the planned projects never reached the implementation stage, in spite of positive results in the feasibility studies and completion of the detailed designs.

In this research, the strategic importance of drawing lessons learned from the planning and implementation phases is recognized, in order to promote a more efficient use of resources. In Ecuador, the planning and implementation phases are led by civil engineering teams in charge of producing feasibility studies, detail design, and the execution of the projects.

As of this writing, eight main transit systems are in operation and one project is under construction (subway). However, four BRT lines and four gondola projects have remained in the planning phase since 2001 in Guayaquil and Quito, respectively. The roots of the decisions that led to the implementation of the systems, or lack thereof, have not been studied or even documented. An extensive literature search shows that rapid transit planning and its decision-making processes in Ecuador have not been the subject of academic research, and the corresponding documentation is scarce. In fact, journal articles and databases show only tangential references to BRT implementation and operational data in a regional context.

### 1.3 Research Objectives

The goal of this research is to develop an understanding of the factors driving rapid transit planning projects and their impacts on the rational planning process and the corresponding implementation likelihood. This thesis examines nine planning processes (18 trunk lines) in Ecuador through the evaluation and quantification of the factors that drove the planning of the three main system components (alignment, size, and technology) and the critical barriers for their implementation. This research presents the only comprehensive analysis of all planned rapid transit projects in Ecuador to date and is based on quantitative and qualitative survey and project data collected specifically for this purpose. The congruence and deviations between theory and practice are then characterized and recommendations are made based on empirical evidence of successful planning processes. The individual research objectives are summarized in Table 1-1:

**Table 1-1 Research objectives and associated methods**

Research Objectives		Method
1	Document and evaluate the processes of the rapid transit projects	Literature Review + Case Study (review of feasibility studies, contractual documents, in-depth interviews, surveys, backward-mapping)
2	Reconstruct the decision-making process for each project	
3	Identify the internal and external factors that influenced the planning processes	
4	Identify barriers for project implementation	
5	Evaluate the relative significance of the factors that influence the planning process	Interviews + Survey + Analytic Hierarchy Process (AHP)*

6	Evaluate the relative significance of the barriers for implementation	Survey + Best-Worst Scaling (BWS)**
7	Characterize and contextualize the factors that influence the planning process and the barriers for implementation and the corresponding effects.	Cross-case Analysis
8	Develop guidelines to support the effective implementation of rapid transit projects	

\* Analytic Hierarchy Process is a methodology for determining the relative measurement of intangible criteria

\*\* Best-Worst Scaling is a methodology to derive a ranking for intangible factors based on discrete choice analysis

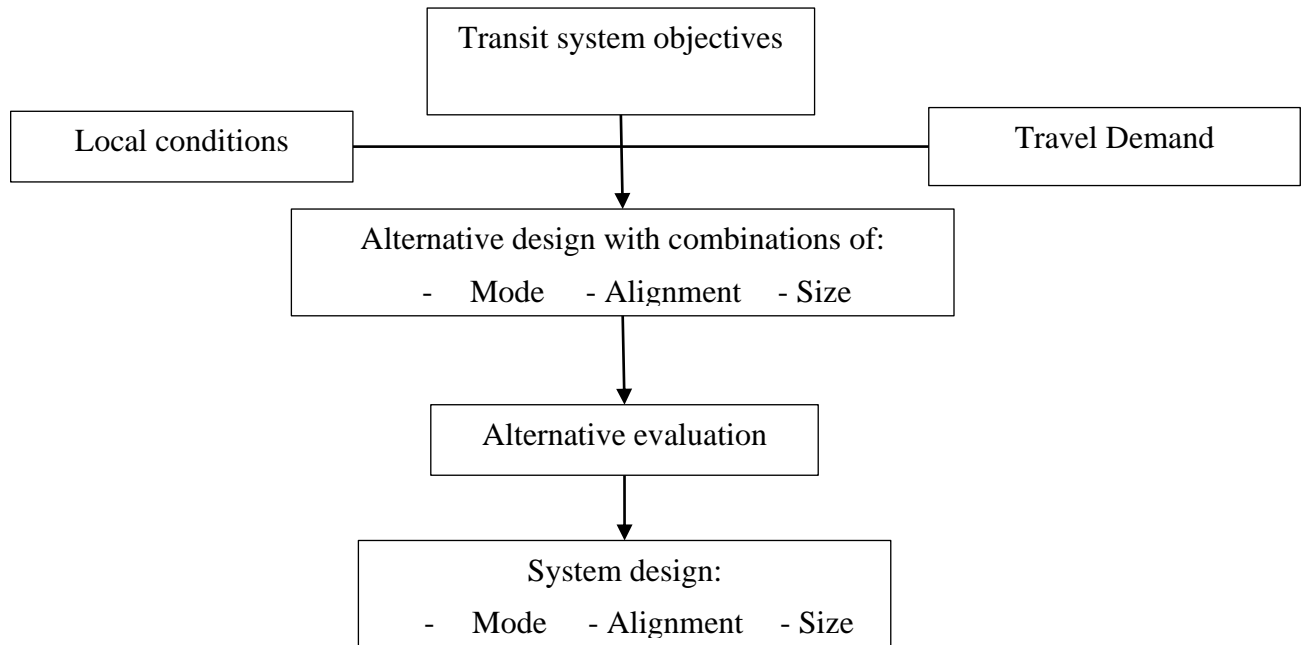
Therefore, this research proposes to examine the key decision points, the forces that shaped the planning process, and their effect on the rational process and implementation outcome. This is of special importance considering the financial burden of such projects in municipal and national budgets. Furthermore, it is especially important to study and identify the drivers of technology selection, given the radical shift in technology selection in recent years that discarded BRT and brought new options for urban rapid transport. The corresponding results are the basis for a set of guidelines tailored to the specific requirements of Ecuador in order to support future planning and implementation processes.

#### 1.4 Scope

This research focuses on the planning and implementation stages of rapid transit projects in Ecuador. In terms of the planning stage, the processes that are the subject of this study are defined as the conceptualization of the projects, which includes all the initial analyses and processes up until the final recommendation of the feasibility study (before detailed engineering design begins). For the implementation stage, the analysis focuses on the barriers that hinder the execution of the physical construction of the project, as well as the measures that overcome them.

The result of the planning process is a final determination of the project's technology, alignment and size of the system. For this research, technology refers to specific vehicles, their mechanical attributes and the right of way (RoW). Alignment refers to the route that the system utilizes between the two terminal stations. Size refers to the physical scope of the system and its components, specifically in terms of number of intermediate stations, transfer stations, terminal stations, and overall span of the trunk line (feeder systems are not included in this definition).

Figure 1-1 shows a simplified concept map of the planning procedure for transit systems based on the data collected for rapid transit projects in Ecuador and academic literature.

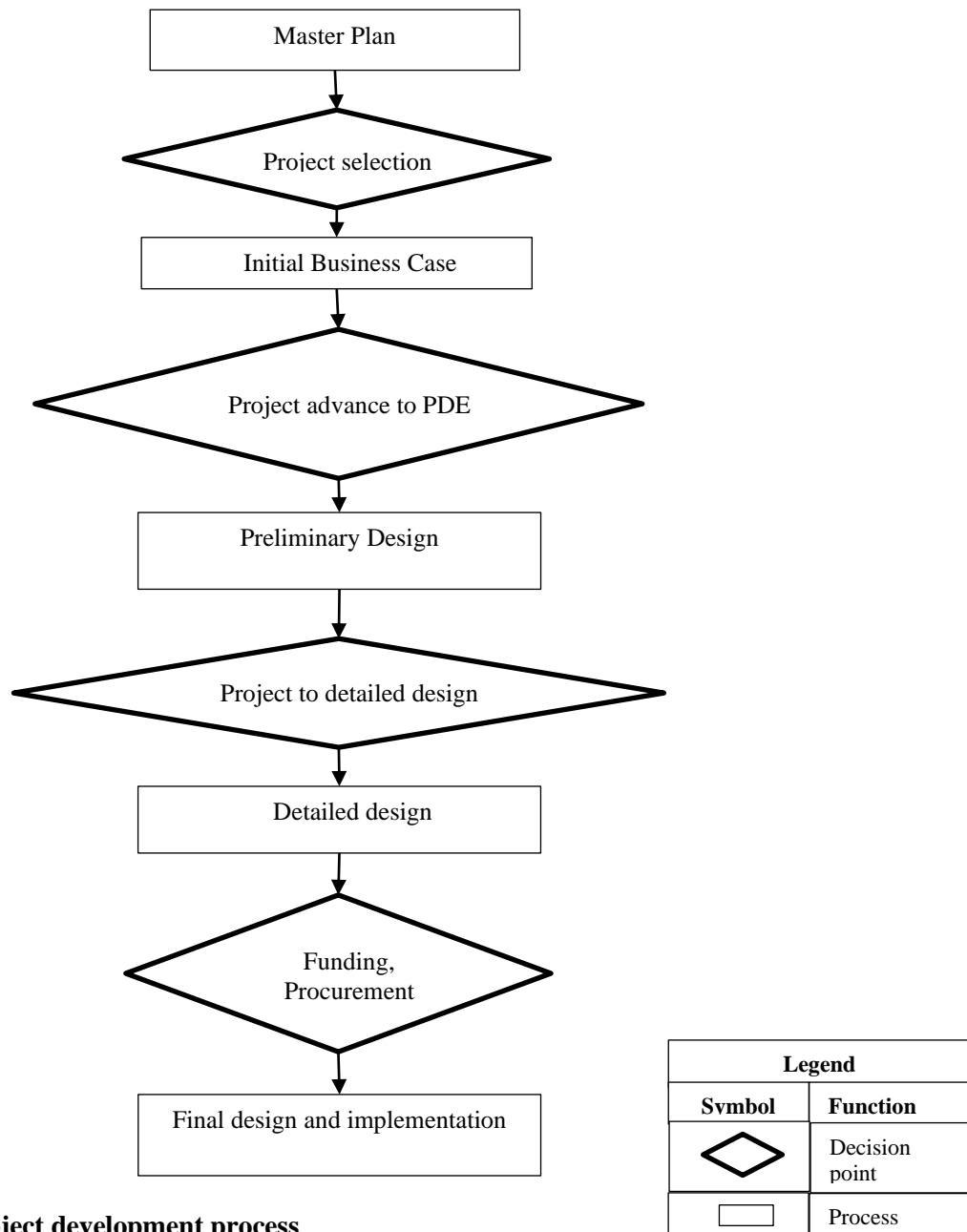


**Figure 1-1 Concept map for transit system planning development procedure**

**Adapted from Vuchic 2005**

For the purpose of this research, and considering existing literature and the processes encountered in Ecuador, the planning, design and engineering for the projects under study includes the following activities: objective definition, assessment of local conditions, demand forecast, mode selection, alignment selection, size definition, and evaluation of alternatives (Meyer & Miller, 2001; Vuchic, 2005).

In the Greater Toronto Area (GTA), Metrolinx calls this stage: “The Planning, Design and Engineering phase 1” (PDE) and includes the development of an initial “Business Case” (Metrolinx, 2017). This stage is the basis to proceed to the Environmental Assessment (EA) process where the project is further developed. Figure 1-2 shows a simplified version of the process established by Metrolinx.



**Figure 1-2 Project development process**

**Source:(Adapted from Metrolinx, n.d.)**

The research includes two categories of transit projects: projects that reached implementation and projects that only reached the planning phase. The implemented projects cover all of the rapid transit project in operation or under construction in Ecuador. The projects subject

to study were identified through a review of literature and public documents. Planning processes started in 1991 in Quito and the most recent processes took place in 2015 in Quito and Guayaquil.

Nine rapid transit planning processes (18 trunk lines) were studied in Ecuador and only half (i.e., 9) of the planned trunk lines reached implementation (see Table 1-2). Metrovia phase 2 (4 trunk lines), Cuenca’s BRT, Quito Cables (4 trunk lines) and Trole Norte remain archived, in spite of having conducted detailed engineering studies, and in the case of Quito Cables Line 1, the expropriation procedures. The scope of the study includes three Ecuadorian cities: Quito (2.9 Million inhabitants), Guayaquil (2.9 Million inhabitants) and Cuenca (0.6 Million inhabitants).

**Table 1-2 Project information**

#	Project Name	Number of trunk lines	City	Planning Year	Planning process	Implemented
1	Trolebus	1	Quito	1991	Individual	Yes
2	Ecovia	1	Quito	1995	Individual	Yes
3	Central Norte	1	Quito	2000	Individual	Yes
4	Metrovia phase 1	3	Guayaquil	2002	Joint	Yes
	Metrovia phase 2	4				No
5	Subway Quito	1	Quito	2010	Individual	Yes
6	LRT Cuenca*	1	Cuenca	2009	Individual	Yes
7	Aerovia	1	Guayaquil	2015	Individual	Yes
8	Quito Cables	4	Quito	2015	Joint	No
9	Trole Norte	1	Quito	2015	Individual	No

\* A previous BRT project using a similar alignment did not reach implementation.

The background documentation compiled for the initial analyses encompasses the feasibility studies, technical notes, contractual documents, public records, and literature for each planning process. Primary data was obtained from in-depth (semi-structured) interviews of the senior technical teams for each project, and two separate surveys to identify the influential planning factors and barriers for implementation. These inputs were analyzed in three distinct stages: first, the analysis of individual cases to reconstruct the decision-making process, and classify drivers and barriers; second, the quantification of the relative significance of the factors and barriers using their respective survey data; and third, a cross-case analysis to compare and contrast projects among each other.

## **1.5 Structure of the Thesis**

The remainder of this thesis is structured in six chapters. First, a literature review that includes the transport planning theory, its criticisms, the specificities for developing countries, the factors that affect the planning process, the barriers for implementation and research specific to Ecuador's rapid transit. Second, a review of the projects' backgrounds, which is segmented by technology and timeframe. Third, a chapter that analyzes the planning stage (i.e., projects' designs), under which the method, the data collection and results for the factors that influence the planning process are presented. Fourth, a chapter that analyzes the implementation stage, under which the method, the data collection and results for the barriers for project implementation are presented. Fifth, an analysis of the effects of private participation in rapid transit projects, by comparing to analogous cases. Sixth, the conclusion and guidelines for effective project implementation, along with the contributions and identified future research paths.



## **Chapter 2**

### **Literature Review**

#### **2.1 Transport Planning Theory and Developing Countries Specificities**

The transportation planning process that was developed since the mid-1950s was based on the concept of rational selection, evaluation of all possible alternatives, leading to the most suitable alternative; often based on minimizing the costs over time (Black, 1990; Meyer & Miller, 2001). Around this time, several transportation plans were developed in North America: Chicago Area Transportation Plan (CATS), Pittsburg Area Transportation Plan (PATs) and the Bay Area Transportation Plan (BATS).

The transportation planning process evolved over time, refining techniques for data collection, forecasting, and coordination with external actors, among others. In the 1970s, community and stakeholder participation were included, along with new legislation that supported transit projects in North America (e.g. Urban Mass Transportation Assistance Act, Joint Highway-Transit Planning Regulations) (Gakenheimer & Meyer, 1979). More recently, a tendency towards the planning and implementation of individual corridors emerged, in part due to the energy crisis of 1970s that increased the importance of individual transit projects for rapid implementation (Vuchic, 2005). This approach was fueled by the nature, complexity and size of rapid transit projects.

Although transit planning processes have evolved over time, the basic concepts and procedures have remain consistent: objective analysis, alternative evaluation, and selection of the preferred alternative (Gakenheimer & Wheaton, 1976; Meyer & Miller, 2001). In particular, theory suggests six major steps: 1) Setting goals/objectives, 2) Defining local conditions/problems, 3) Estimating demand, 4) Determining feasible alternatives, 5) Design of alternatives (alignment, size and technology combinations), and 6) Evaluation of alternatives (Garber & Hoel, 2009; Meyer & Miller, 2001; Vuchic, 2005). This research focuses on this procedure, with emphasis on the design and evaluation of alternatives (steps 5 and 6).

The estimation of demand and the assessment of local conditions are crucial factors (internal to the project) for designing and evaluating feasible alternatives, including combinations of potential alignments, sizes and technologies (e.g., BRT, Light Rail Transit (LRT)) (Vuchic,

2005). Projects can have more than one feasible technology, as their characteristics and transport capacity overlap. Cervero (2013) provides general ranges for capacity: BRT (5,000 to 45,000 passenger per hour and direction (pphd)), LRT (12,000 to 27,000 pphd) and heavy rail (40,000 to 72,000 pphd). This overlap sometimes leads to debates of a “superior technology”, however the most appropriate technology depends on the specificities of the project and its context (Casello, Lewis, Yeung, & Santiago-Rodríguez, 2014; Vuchic, Stanger, & Bruun, 2013).

In this vein, the demand estimation and its impact on the feasible technologies has two major implications for project planning. First, the demand estimate should provide enough accuracy to evaluate ranges of feasible technologies. In the case of Ecuadorian BRTs, the demand in peak hour varies from 7,000 to 11,000 (pphd). This indicates that two technologies are feasible and should be evaluated (BRT and LRT), and also that the estimations should reach values close to 40,000 (pphd) to include heavy rail in the evaluation process. Hence, for the evaluation of feasible alternatives, the accuracy of demand estimation has some flexibility, as the inclusion of feasible technologies with higher capacities requires large differences in demand. Second, successful rapid transit projects are not necessarily projects that reach their maximum estimated demand in a short time frame. Rather, forecasts require accuracy levels that allow the evaluation of adequate technologies during a project’s lifespan. Furthermore, these feasible technologies should maintain minimum standards for service levels during the lifespan of the project.

Adapting the planning process to emerging economies is of great importance (Dimitriou, 1990; Dimitriou & Gakenheimer, 2011; Gwilliam, 2003), because of the different characteristics of these cities (Cadot, Röller, & Stephan, 2006; Vuchic, 2005). Dimitriou (1990) studied the application of the transport planning process in emerging economies and highlighted the relevance of generating transport planning specifically for developing cities. Vuchic (2005) emphasizes that problems in developing cities present different characteristics and are accentuated by the lack of space and economic conditions to accommodate infrastructure growth. Dimitriou (1990) described the importance of tailoring the process to the context of these cities through the study of different cases. Ortuzar and Wilumsen (2011) also identified the difference in context of emerging countries vis a vis the transport modeling procedure and recommended a tailored approach. In the same line Doderó, Casello and Molinero (2011) found that transit planning in developing countries requires larger emphasis on the costs and effects that incumbent operators absorb. For instance, the apparent

efficiencies in operational savings of rail are less applicable to settings with lower labor costs and higher capital costs.

Moreover, differences in design standards and exceptional cases require special considerations. For instance, developing cities use six passengers per square meter for demand ridership, while developed counterparts use four. Moreover, the peak capacities for BRT of 45,000 pphd observed in Bogota (Hensher, Golob, Hensher, & Golob, 2008) are exceptional and hard to replicate (Gilbert, 2008). This difference in design standards is partially explained by the necessity to minimize capital costs and the presence of transit captive riders. Hence, the design focus shifts to transporting more passengers with fewer vehicles as demand becomes inelastic.

## **2.2 Transport Planning Limitations**

The transport planning process was initially criticized, in part, due to the fact that it was disconnected from political and community input, as well as a lack of qualitative assessment in the recommendations. Other weaknesses of the process were later identified, including the general technical consensus of auto-oriented development (Altshuler & Curry, 1975), the use of trend extrapolation, the consideration of fixed demand, disregard of other modes, and vague understanding of the city to transportation relationship (Vuchic, 2005). Vuchic (2002) elaborates on this subject and presents four main “misconceptions” that led transit planning from 1950s to the 1970s: non tolerable transfers, mutually exclusive choices between buses or rail for rapid transit, low accessibility for rapid transit (fewer stops), and flexible transit services as a goal.

In the last decades, the planning and design of rapid transit projects have been subject to criticism based on the variance between the findings of the studies and actual results of the implemented projects. It has been argued that the transportation planning process lacks accuracy for an important share of projects, especially in demand and cost estimation. A study of 210 transportation projects conducted by Flyvbjerg, Holm and Buhl (2013) showed that: “For nine out of ten rail projects passenger forecasts are overestimated; average overestimation is 106 percent”, moreover, “Forecasts have not become more accurate over the 30-year period studied”, and concludes that there could be a systematic problem of misinformation. Pickrell (1992) states that for rail projects in North America, the bias can be partially explained by the financing scheme and structures of federal transit programs and local mechanisms and underlines the importance of technical staff assessing and communicating financial and political risks. In emerging economies,

financiers, such as development banks, play a key role in establishing policies and objectives that influence project configuration. In this context, it can be hypothesized that the technical procedures of demand estimation may not be the root of the problem, but the influence of external factors that introduce additional elements in the technical process (e.g., financing mechanisms).

From a wider perspective, the study of megaprojects in different sectors (i.e., projects that require over a billion US dollars of investment and require several years to develop and implement) -including rapid transit- has shown similar influences (e.g., financial, political). Flyvbjerg (2009), based on statistical analyses of such projects, argued that they are systematically subject to the “survival of the unfittest” which show the best numbers are built in detriment of projects that present less optimistic estimations. However, the results show large differences between estimations and actual project figures (i.e., overbudget and overtime). The increase in accountability for the estimations, a reference class forecast method and increased transparency are proposed as measures to improve these outcomes.

### **2.3 Factors Affecting the Planning Process**

In literature, the external intricacies affecting transit planning point to a multitude of factors, which can be grouped in three main areas: financial, social, and political. Pickrell (1992) identified a bias in planning that was partially explained by financing schemes in North America. Edwards and Mackett (1996) studied the decision-making process for the development of new urban transport in England and concluded that the technical decisions of the transport planning process were rational but the context, policy, and legislation, made the final decision irrational. The domain of political interventions in transit infrastructure decisions is viewed as a key area of research (Samuel Carpintero & Siemiatycki, 2016), not only in engineering, but in economics where similar political distortions can be found (Cadot et al., 2006). Moreover, in Spain, not only political, but social and financial factors have had strong influence in alignment selection (Samuel Carpintero & Siemiatycki, 2016).

In emerging economies, financial, political and social factors, play larger roles in establishing policies and objectives that influence project configurations, due to their inherent characteristics (e.g., low financial resources, lack of space, social conflicts, weak institutions (Cadot et al., 2006)). For Latin America, the factors affecting the planning process have been

analyzed mainly through the lens of barriers (institutional, financial, social and political) to planning and implementation (Lindau, Hidalgo, & Almeida Lobo, 2014; Wu & Pojani, 2016).

Ardila (2007) compared two projects in Bogota, the implemented BRT system and the planned subway Line as well as the processes of BRT versus LRT in Curitiba. It was found that the political actors had a predetermined alternative regarding the mode to be implemented, generating an initial constrain to the project's design. Additionally, it was found that the technical teams that designed the projects were not only technically capable but politically capable. This particular trait permitted the rise of project champions to lead the projects within the teams and also the much-needed interaction with politicians. In this context, the technical teams played a key role in balancing the interest of stakeholders and politicians. The mediation of the technical staff reduced power imbalances and the feedback from stakeholders and politicians resulted in modifications to the original system design in order to generate a project that reached implementation. Furthermore, it is argued that the projects will not reach implementation if variables key to decision-makers are not addressed during the planning/design process. In the same line, Ardila and Salvucci (2001) found evidence that effective planning of rapid transit projects requires considering and merging engineering and planning with public finance, political, social and economic factors.

In these cases, the technical staff were able to interpret and manage the external influences to successfully implement the projects. However, over-interference of external factors remains a high risk (Ardila, 2004). A similar context was present in Quito's first BRT planning process, where the influence of social, political and financial factors hindered the implementation and impacted the final design (Chapter 6), but it is unclear to what extent the design and the implementation were influenced and if the subsequent projects were in similar situations.

In this line, external influences in project planning can also have a positive effect. Dimitrou (2014) found that the success of mega transport project's depended, among other factors, upon embracing the impact of contextual forces; and that a purely technical approach that denied external influences often resulted in delays and cost escalation. Hence, it can be said that the outcome in terms of projects' implementation efficiency depends to a certain degree on external influences during the design process. For Bogota, embracing external factors (i.e., political and financial) was key for alternative evaluation and implementation. Thus, it is important to understand how factors of

planning processes shaped the outcomes of different transit projects. A summary of the factors that affect rapid transit planning according to existing literature is presented in Table 2-1.

From a decision-making perspective, Miller and Meyer (2001) identified five major decision-making models. First, the ‘Rational Actor’ approach, in which the alternatives are evaluated and selected in order to maximize certain variables (e.g., travel time, costs); second, the ‘Satisficing’ approach, where the first alternative that meets minimal standards/thresholds is selected; third, the ‘Incremental’ approach, where the alternatives prioritize moving away from problems, in detriment of attaining the objectives; fourth, the ‘Organizational Process’ approach, in which organizational structures have large influences in the selected alternative; and fifth, the ‘Political Bargaining’ approach, in which the process is pluralistic and conflicts and bargaining arise.

**Table 2-1 Literature findings for factors that affect rapid transit planning**

<b>Publication</b>	<b>Country / Region</b>	<b>No. of projects/cities and Method</b>	<b>Technology</b>	<b>Factors/Effects</b>
Pickrell, 1992	USA	Eight US cities / Quantitative for accuracy of forecasts (ridership, costs)	Rail (light and heavy)	Financial
Edwards & Mackett, 1996	England	Eleven projects / Qualitative: decision-making process analysis	Rail and bus	Technical, financial, political
Ardila & Salvucci, 2001	N/A	Qualitative: theoretical model to plan large transport projects	Rail, Bus (BRT)	Political, financial and technical
Cadot et al., 2006	France	22 regions / Quantitative for impact of transport infrastructure investments on econ. growth	Rail, bus, roads	Political
Ardila, 2008	Bogota	Qualitative: Case study	Rail, Bus (BRT)	Political, social and technical
Lindau et al., 2014	Latin America	Qualitative: Multiple case study	Bus (BRT)	Institutional, financial, social and political
Dimitriou, 2014	UK, France, Greece, Germany, Netherlands, Sweden, USA, Australia, Hong Kong, Japan.	30 projects / Qualitative: multiple case study, decision-making analysis	Rail, bus, airport	Political, social, financial and technical
Carpintero & Siemiatycki, 2016	Spain	Two systems / Qualitative: decision-making process analysis	Rail (light)	Political, social
Wu & Pojani, 2016	Bangkok	Qualitative: Single case study	Bus (BRT)	Political

## **2.4 Barriers for Rapid Transit Implementation in Developing Countries**

In developing cities, bus-based systems are predominant (i.e., BRT), in part because of the low capital requirements and short implementation times. The use of rail systems (LRT and heavy rail) and other technologies (i.e., urban gondola) are not common. Only a handful of cities in Latin America have implemented subways and even large cities, like Bogota (7 million inhabitants) and Guayaquil (3 million inhabitants), rely on BRTs.

Curitiba, and subsequently Quito and Bogota, pioneered the implementation of BRT systems and gave way to research regarding their planning and implementation (Lindau, Hidalgo, & Facchini, 2010; Wright, 2007; Hidalgo & Carrigan, 2010). As these systems expanded throughout the world, several barriers were identified, ranging from those that are country specific, to transferable and generalizable results (Hidalgo & Graftieux, 2008; Lindau, Hidalgo, & Almeida Lobo, 2014; Nguyen, Ha, Tu, & Nguyen, 2019). The most relevant barriers include lack of stakeholder alignment, inadequate funding, optimism bias, and lack of political leadership/commitment (Lindau et al., 2014; Nguyen et al., 2019; Wu & Pojani, 2016). However, the literature shows an imbalance with respect to other modes (i.e., rail, gondola). Moreover, studies focused on more than one project are almost exclusively focused on BRTs. Studies focusing on other modes show results tangential to the topic of barriers (Garsous, Suárez-Alemán, & Serebrisky, 2019), and hence technology specific barriers remain unclear.

Only two studies regarding project implementation were found to address more than one technology. One study examines the case of Bogota, where a subway project failed to reach implementation, and a BRT effectively completed the process, based on institutional capacity and planning driven by implementation (Ardila, 2002). The second study highlights the differences for implementation of BRTs and gondolas in Colombia: management of competing modes, institutional capacity, and complementary investments in urban environment (Bocarejo, Velasquez, & Galarza, 2014). These findings from two Colombian cities helped contextualize solutions for the two technologies. Such work is yet to be developed for other Andean countries. Although barriers are known in literature, it's unclear if they are technology specific or transferable to neighboring settings (i.e., country specific). Moreover, there is no research regarding their relative importance, thus critical barriers, or combinations thereof, remain unknown. Table 2-2 presents a summary of the barriers for rapid transit implementation that have been identified in previous literature.



**Table 2-2 Literature findings for barriers of rapid transit implementation**

<b>Publication</b>	<b>Country/Region</b>	<b>No. of projects/cities and Method</b>	<b>Technology</b>	<b>Identified barriers for implementation</b>
Ardila, 2002	Colombia	Two projects: Bogota / Qualitative: multiple case study	Bus (BRT) / rail	Financial, political, technical and institutional
Dario Hidalgo & Graftieaux, 2008	Latin America / Asia	12 projects / Qualitative: multiple case study	Bus (BRT)	Institutional and financial
Lindau et al., 2014	Latin America / Asia	Qualitative: multiple case study	Bus (BRT)	Institutional, technical, political, social, financial
Bocarejo et al., 2014	Colombia	Two projects: Medellin, Cali / Qualitative: multiple case study	Gondola, bus (BRT)	Political, technical, institutional
Wu & Pojani, 2016	Thailand	One project: Bangkok / Qualitative: case study	Bus (BRT)	Political, technical
Nguyen et al., 2019	Vietnam	One project: Hanoi / Qualitative: case study	Bus (BRT)	Institutional, technical, political, social, financial

## 2.5 Rapid Transit Planning in Ecuador

Rapid transit projects in Ecuador were first implemented in 1995, with the BRT line named Trolebus in Quito. Later on, two additional lines were implemented “Ecovia” and “Central Norte” (CN). Guayaquil followed this trend and started the implementation of BRT trunk lines in the early 2000s: “T1”, “T2” and “T3”. Recently a new wave of projects has taken center stage, Quito’s first subway line, Guayaquil’s first urban gondola and Cuenca’s first Light Rail Transit (LRT). Little research can be found on these systems as efforts to date have focused exclusively on the characteristics and results of implemented BRTs (D. Hidalgo & Graftieaux, 2005; Lindau et al., 2014; von Buchwald, 2007) (i.e., what was built and how it performs), rather than analyzing the factors that shape transit planning and its implementation. Other studies have mainly centered upon the project’s cost and patronage in a regional context (Lindau, Hidalgo, & Almeida Lobo, 2014).

Thus, the questions of why and how these systems came to fruition remain unanswered. Moreover, rapid transit systems using technologies other than BRT, have not been the subject of academic research, nor have the projects that have not yet reached implementation (nine out of eighteen for Ecuador).

Aside from these studies, there is no specific or tangential research on rapid transit implementation in Ecuador either. This deficiency coupled with a dissociation between the theoretical rational planning approach and the context and governance of projects generates a gap between theory and practice. This gap previously detected in developed cities (Marsden & Reardon, 2017) is more acute in developing counterparts, because of the complexities in governance and socio-economic interactions.

## **2.6 Literature Gaps**

Based on the literature review the following gaps were identified:

1. Ex-post evaluation, decision – making and political interventions in transport projects are areas of key research, where few studies have been conducted, particularly for developing countries.
2. Studies of transport project implementation have focused mainly on roads (highways) and investment strategies (e.g., multilateral agencies). The little attention given to transit projects is centered on specific modes (e.g., BRT) rather than addressing transit in a holistic approach. Moreover, there are few ex-post analyses of rapid transit implementations in developed cities, and it is a greenfield for research in developing cities.
3. Developing cities present particular contexts that require different approaches for rapid transit implementation. General research in the transit sector in Ecuador is extremely sparse and this research is the first to address the issue.
4. Research shows that external factors (political, financial, social) influence a project's planning and ultimately barriers that hinder its implementation. However, research is limited to qualitative approaches, as no prior studies have tried to quantify the extent of the external influences and barriers on rapid transit project implementation (Table 2-1 and Table 2-2).

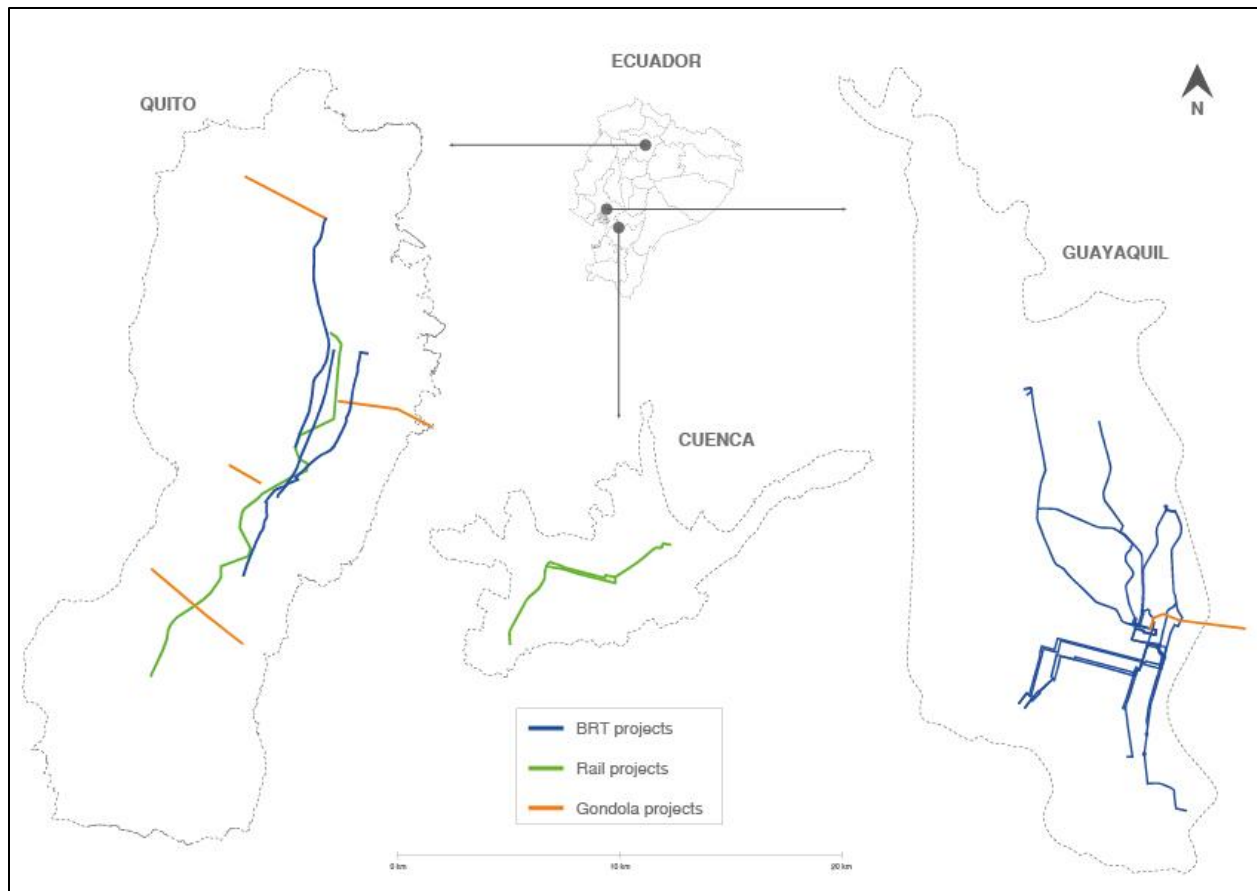
5. Dimitriou (1990) showed that external interference is necessary to make transport projects feasible. Similarly, research from Bogota revealed that projects will not reach implementation if variables key to decision-makers are not addressed during the planning/design process (Ardila, 2002). However, it remains unclear how to find the range of effective balance between external and internal drivers.
6. The effective implementation of rapid transit projects has not been analyzed from a strategic engineering perspective. The role of the technical team in balancing the internal and external factors through interaction with decision-makers is yet to be documented, studied and framed as guidelines for future projects in Ecuador.
7. Finally, the transferability of country and technology specific barriers is unclear, as a limited number of studies have been conducted and limit their scope to specific projects without evaluating results for analogous settings.

This is the first research endeavor that seeks to understand how Ecuador's rapid transit planning processes were affected by different factors and characterize their impacts on the rational planning process. A deeper understanding of the empirical reasons behind project implementation, or lack thereof, will contribute to bridge this gap and to expand the rational approach that technical teams often exclusively utilize. Chapter 4 and Chapter 5 analyze the factors that affect the planning process and the barriers for implementation, respectively. In both chapters, the analyses are approached from qualitative and quantitative perspectives, thus addressing the gaps of research specific to Ecuador: lack of quantitative studies and lack of ex-post project evaluation. Chapter 6 analyzes the effects of private participation in BRT projects and Chapter 7 addresses the lack of guidelines for application in future processes.

## Chapter 3

### Projects' Characteristics and Planning Processes

This section presents an overview of the projects' characteristics and planning processes with a qualitative introduction to factors that affected these processes. The content is divided into five project clusters of similar characteristics and chronology: BRT systems from 1991 to 2000 (3 projects: Trolebus, Ecovia and Central Norte), BRT systems from 2002-2004 (7 projects: T1, T2, T3 implemented and T4-T7 remain in planning stage), rail projects from 2009 to 2015 (2 projects: Cuenca Tranvia and Quito Subway), urban gondola projects 2015 to 2018 (5 projects: Quito cables 4 lines, and Aerovia 1 line), and a BRT system planned in 2015 (1 project: Trole Norte). For each project, the most relevant features are presented in the context of the planning processes and are discussed because of their distinctiveness with respect to the other projects. Figure 3-1 shows the location of Quito, Guayaquil and Cuenca along with their respective rapid transit projects.



**Figure 3-1 Rapid transit systems planned in Ecuador from 1991 to 2018**

### **3.1 National Context for the Rapid Transit Projects**

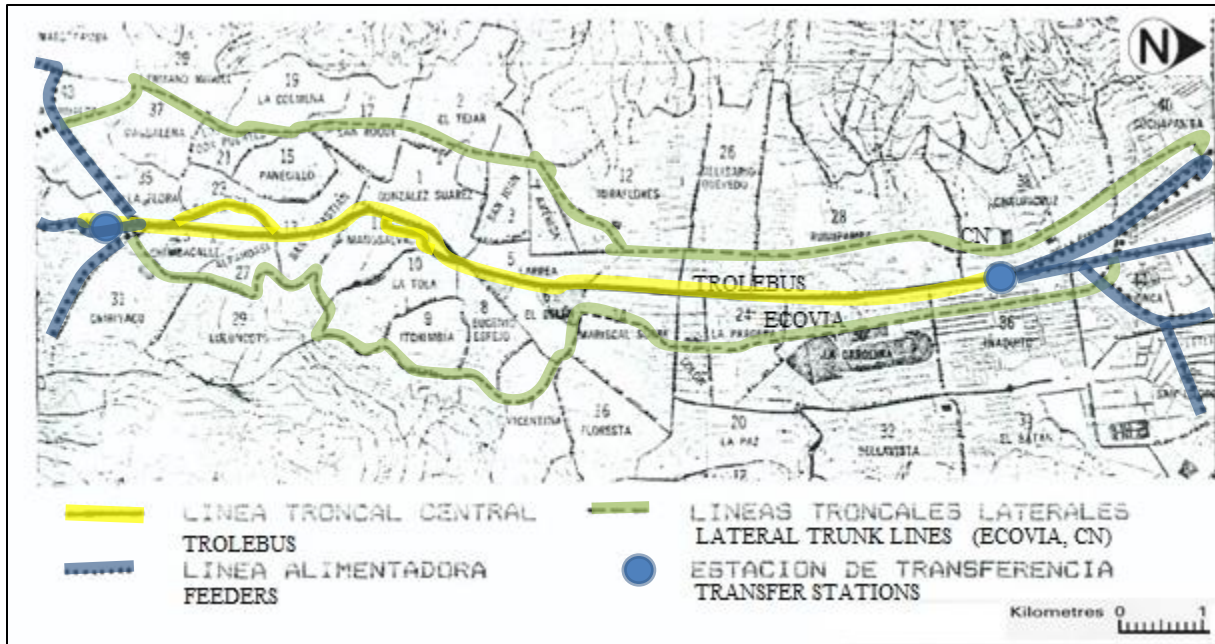
The specific context of Ecuador is of relevance for this research. Comparable elements to neighboring countries can be found, but there are also particular circumstances unique to Ecuador. From a social perspective, the transit services have been provided by private operators, similar to other developing countries. These operators work under the “one man, one bus” model, which implies an atomized sector (i.e., large number of individual operators), with vehicle owners grouped in clusters called ‘cooperativas’, which control particular routes. It is common for the owners to be the drivers and their work as transit service providers is essential for their livelihood (i.e., difficult transitions to other sectors). This phenomenon is similar in other developing countries, for instance Mexico (A Lopez Doder, Casello, Vazquez, & Molinero, 2013).

From an environmental perspective, the rapid transit planning processes have generally prioritized initial investment costs over environmental considerations. The causes are directly related to the costly access to financing and scarce financial resources. An indicator of the non-prioritization of environmental elements are the fuel quality standards. As of 2020, Ecuador's diesel standards only permit the utilization of Euro III standards for diesel engines, whereas Europe and other Latin American countries have transitioned to Euro VII standards (i.e., lower emissions).

In terms of the political landscape, Ecuador presents an unstable environment, which is reflected in the constant change of elected officials (e.g., seven different presidents were appointed from 1996 to 2005). Concurrently, the financial environment is affected by this instability. The country risk reflected in the interest rate applied to national bonds has been much higher than neighboring countries (i.e., Colombia, Peru), and in the last ten years has fluctuated between 400 and 6000 points (i.e., the expected return rate for national bonds varied from 4% to 60% in the international markets). This creates complex and costly access to financing for rapid transit and other projects. Nonetheless, in this complex context, the technical teams have managed to plan and implement rapid transit systems in three different cities.

### **3.2 Group A: Quito BRTs (1991 – 2000)**

Quito, the capital of Ecuador, implemented the first formal transport planning process that addressed transportation issues, including the management of unorganized informal private operators. Quito is located in a narrow valley and surrounded by mountains, forcing its lateral expansion. The BRT system follows the geographical layout of the city and is comprised of three north-south corridors parallel to each other. Figure 3-2 shows the initial planning concept for the system, which evolved over time but kept its basic principles: one backbone (Trolebus) and parallel lines (Ecovia and CN).



**Figure 3-2 Planning concept for integrated transport system in Quito, 1991**  
 (C. Arias, Guerrero, Pazmino, & Villota, 1991)

### 3.2.1 Trolebus

The planning for Trolebus started in 1991. It encompassed a central trunk line, a city-wide restructuring of the bus system, and a new legislation that included assuming transit competencies (previously held by the national government) (Chapter 6). The feasibility study (FS) followed a traditional structure, starting with diagnosing the current situation (including the incumbent’s circumstances) and setting goals and scope boundaries for the project. A travel demand model was developed and calibrated to replicate the existing conditions. However, a household survey was excluded due to financial and logistic barriers, as well as data limitations (land use, employment). Instead, an intercept bus survey was used to develop the origin-destination (OD) matrix. It was also assumed transit users were captive and no modal changes would occur.

The analysis of alternatives started with the alignments, including several combinations of paths and terminal station configurations, in order to maximize the ridership forecast. Then, the analysis continued to technology alternatives, which are the subject of a large separate document, comparing heavy rail, LRT, articulated trolleybuses, articulated buses and 12-meter buses.

A complete economic lifecycle cost analysis for the various technology alternatives (20-year horizon) showed trolleybuses were preferable due to their electric motors (20-year life, low maintenance) compared to diesel buses (8-year life, high maintenance). Trolleybuses also required a smaller investment and had lower operational costs compared to LRT. The analysis also anticipated the potential future need to upgrade the system to a rail configuration due to increases in demand. This consideration added another advantage to the trolleybuses' electrical infrastructure, which was designed to accommodate an upgrade to LRT if or when necessary. A final evaluation of the preferred alternative is presented covering financial, socio-economic and environmental assessments. This is the only project in Ecuador that presents such a detailed evaluation of feasible alternatives.

The system's planning, detailed design and financing processes spanned two political cycles, dominated by one political party, and started operations in 1995, complying with almost all of the original FS recommendations. The only recommendation overlooked was the concession of the operation to a private partner (not incumbents). The scheme for the concession was outlined and recommended in the FS. Incumbents (a social factor) were regarded as a potential source of conflict, but had no influence in the selection of the preferred alternative.

The Trolebus was designed as a three-phase plan (Center, South, North). The first phase was subdivided in stages of gradual implementation as the complexity of the project and local expertise were limiting factors. The FS estimated 10 months for implementation of Phase 1 (C. Arias et al., 1991). The initial investment was estimated at 40.3 Billion Sucres (Ecuadorian currency at the time) equivalent to \$110.5M USD in 2017 for Phase 1, stages 1, 2 and 3. Figure 2 shows the original estimated investment costs.



CUADRO No. VII 1.1  
COSTOS DE INVERSION EN PAVIMENTACION DE VIAS,  
CONSTRUCCION DE ESTACIONES DE TRANSFERENCIA, TERMINALES  
Y ADQUISICION DE EQUIPO  
(En millones de sucres)

ETAPAS	PRECIOS DE MERCADO			PRECIOS DE EFICIENCIA		
	1era. 1992	2da. 1997	3ra. 2002	1ra. 1992	2da. 1997	3ra. 2002
ESTUDIOS Y DISEÑO	115.74	1.54	35.39	115.74	1.54	35.39
FISCALIZACION	96.45	1.28	29.49	96.45	1.28	29.49
ADMINISTRACION	231.82	3.08	78.78	231.82	3.08	78.78
OBRA CIVIL						
M. U. Calificada	194.45	2.83	65.18	194.45	2.83	65.18
M. U no Calificada	182.24	2.30	52.80	111.16	1.40	32.21
Componente Nacional	981.71	11.28	259.06	981.71	11.28	259.08
Componente Importado	558.73	9.27	212.84	586.67	9.73	223.48
Combustible	14.85			24.95		
ELECTRICOS	1.991.68	56.58	257.18	1.991.68	56.58	257.18
EQUIPO IMP. MAI. ELECTRICO	8.983.20			9.452.36		
IMPORCIACION TRULLEY-BUSES	17.582.25	2.413.28	3.447.58	18.461.31	2.553.86	3.619.87
EQUIPO ADMINISTRATIVO	59.20			59.20		
EQUIPO MAQ. NACIONAL	492.50			492.50		
EQUIPO IMP. REPUBS.MANI.	1.477.50			1.551.38		
DISEÑO ELECTRICO	492.5			517.13		
TOTAL	33.454.74	2.501.28	4.438.13	34.848.43	2.621.58	4.592.58

FUENTE : IMQ, UNIDAD DE ESTUDIOS DE TRANSPORTE  
ELABORACION: UNIDAD DE ESTUDIOS DE TRANSPORTE

**Figure 3-3 Estimated capital expenses of Trolebus project  
(C. Arias et al., 1991)**

In December 1993 the contract for financing was signed, after a difficult and long process, and the construction of infrastructure started in mid-1994. This project faced fierce opposition from incumbent operators, due to the transportation reform which included limiting bus life span to a 20-year maximum (thereby excluding 1,106 buses (Chauvin, 2007)), and changes in routes along the corridor. The municipality decided to take a Design, Bid, Build, Multi-prime (DBBMP) approach, since it was the first project of its kind, and no expertise was available locally to assume the complete execution.

In December 1995, phase 1 (first stage) was inaugurated (12 months from financing agreement signature). The forecasted demand of 123,000 trips per day for phase 1 and 150,000 with phase 2 was quickly attained and surpassed, and by the end of 1996 the system was transporting 170,000 passenger per day (Chauvin, 2007) prompting the addition of new trolleybuses. The final costs for Phase 1 and 2 of the project were reported at: 5.1M USD per km for 17 km trunk line (D. Hidalgo & Graftieaux, 2005).

### **3.2.2 Ecovia**

The Ecovia corridor was part of the original 1991 plan and runs parallel to Trolebus on the east side. It presents two fundamental differences from its predecessor: first, diesel vehicles instead of trolleybuses and second, central stations instead of right-side stations. The latter responds to two main reasons: first the alignment's cross-section was narrow and prevented having right-side stations, second reducing the number of intermediate stations in half helped the limited budget.

The planning started shortly after the Trolebus FS was completed (in 1993) and occurred amidst a severe economic crisis. The municipality had very limited resources and took advantage of a national credit line for road paving to implement the segregated lanes. Hence, this corridor was set up as the restructuring of an avenue rather than a transit system, due to the administrative requirements to access the needed funding. The concept did not include a change to bus routes, but rather the improvement of the RoW, stations, and vehicle characteristics. The municipality would provide the fixed infrastructure (i.e., lanes, terminals) and the incumbents would provide the vehicles. It was hoped that this was a scheme that, if successful, would promote similar endeavors in the future.

Technology selection was limited by two main factors: financial and social. A financing threshold was self-imposed by the technical team to ensure the possibility of implementation. Additionally, the inclusion of incumbents was required in order to start a process of more formal and technical operations.

In this case, there was an ex-ante technology definition to ensure incumbent participation. The technical team considered the use of articulated diesel buses as the only viable solution for incumbent inclusion, due to their financing capabilities and necessary returns on investments. In terms of alignment and size, the plan followed the existing informal corridor pattern (demand and street network), without significant influence from external factors.

The planning agenda considered private operation from the conceptual design and former operators were given the first choice through a consortium in charge of the articulated buses acquisition and operation. This consortium (Tranasoc) could not complete the financing on time, and in March 2001, the municipality decided to acquire the vehicles directly in the midst of a major

political change. This change brought a new vision to the city, which formerly was oriented by one political party (1989 to 2000).

The project presents particular features such as executing as much infrastructure as possible with the municipality's internal capacities and a fragmented DBBMP, probably trying to accommodate the execution as funding became available.

The demand estimate for the year 2000 forecasted 140,000 passengers per day (Gamboa, Arias, Castillo, & Hermosa, 2000). In November 2002, Ecovia started operations. However, the concession process wasn't completed, in part because of internal conflicts in the consortium (credit constraints, legal issues) (Chauvin, 2007). In February 2003, the concession agreement was signed and publicly acquired vehicles were privately ran by the consortium. Eventually, this corridor was operated by the municipality.

In spite of being conceptually planned for private operation, this corridor couldn't successfully complete the intended PPP. Ecovia reports final costs of 2.1M USD per km (9 km. span) and a daily ridership of 81,000 passenger in the trunk line (2006) (D. Hidalgo & Graftieaux, 2005) (Menckhoff, 2005).

### **3.2.3 Central Norte (CN)**

With the new political vision in 2001, began the planning of CN. This corridor was advertised as a second generation of BRT systems and was designed with two lanes per direction, right hand side stations and longer distances between intermediate stations (operational speed was given additional importance in detriment to accessibility) (Chapter 6). The Central Norte (CN) had two planning phases: the conceptualization (original transit plan from 1991) and the feasibility study. The alignment and technology differ in these phases. The original plan selected a different set of streets for the alignment and recommended trolleybuses for the operation. The change in alignment was the result of a new vision from the technical teams.

The infrastructure work started in September 2002 and the inauguration was planned for June 2003. Financial issues caused delays and, finally in 2004, the project began partial operations (Chauvin, 2007), but the infrastructure was not completed. Regular operation was only achieved in November 2004 (excess of one-year delay).

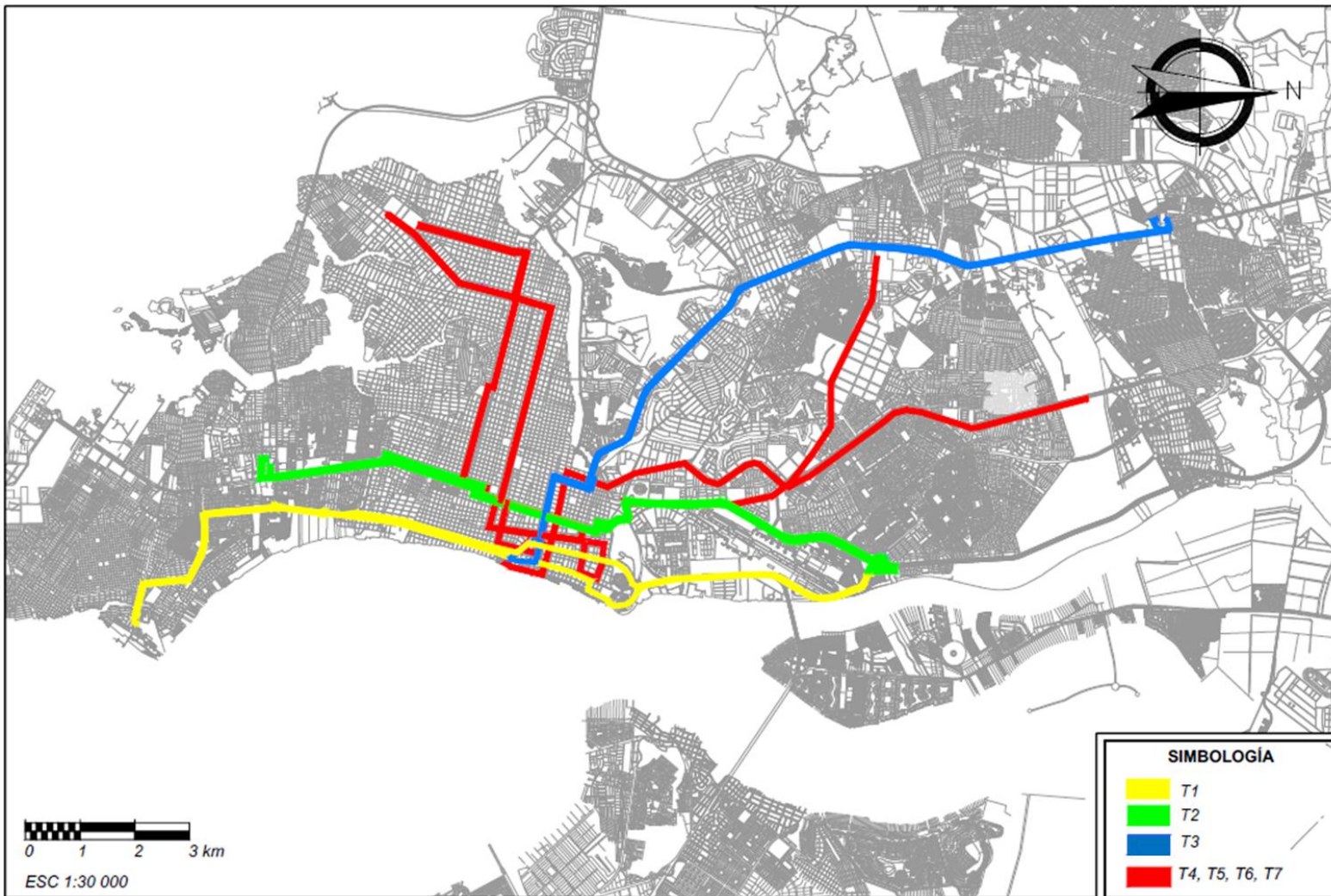
This project was also planned as a concession for the operation of several incumbent groups that ran in this corridor previously. This second attempt at incumbent participation proved difficult (Chapter 6) and constrained the technology to diesel articulated buses yet again. Surprisingly the agreement to operate the corridor was executed after the start of operations in May 2005 for a 12-year concession. The final costs of this project were 3.3M USD per km (11 km span) (D. Hidalgo & Graftieaux, 2005) (Menckhoff, 2005).

This corridor presented major differences between demand estimates and actual ridership. The expected demand was 400,000 passenger per day (D. Hidalgo & Graftieaux, 2005) but the actual ridership only reached 120,000 in 2006. Contrary to Ecovia, this corridor was able to operate with private buses for the time of the concession, although not without complications.

### **3.3 Group B: Guayaquil BRTs: Metrovia (2002)**

The Metrovia system is located in Guayaquil, where the transit system presented similar difficulties as in Quito (i.e., informal incumbent operators, lack of municipal transport planning). This informal transit operation was identified as problematic by the municipality in the early 2000s and triggered the proposal for the first public transport planning process.

Metrovia's projects are a part of the city's transport plan entitled "Plan for the rationalization of the mass transport of Guayaquil-Metrovia". Planning began in 2002 and benefited from the technical assistance of the United Nations Development Program (UNDP) and former staff from Quito's planning agency. This plan contains a vision of the public transit system of the city with a 20-year horizon and develops a FS for seven trunk lines. Three of these trunk lines were selected for the first phase of detailed study and implementation (T1, El Guasmo – Terminal Río Daule (2007); T3, Bastión Popular – Centro (2009) and T2, Terminal 25 de Julio – Terminal Río Daule (2012)). Figure 3-4 shows the rapid transport network vision with the existing three trunk lines and the four remaining projects (not yet implemented).



**Figure 3-4 Trunk lines' plan for Guayaquil**

(Arguello, Medina, von Buchwald, Paranhos, & Arias, 2004)

For this planning process, the Mayor and City Council established specific guidelines. This is the only case where the decision-makers' guidelines are explicitly stated in the FS, among the most relevant:

- Transit service must use resources efficiently, capitalizing on existing infrastructure and vehicles.
- Strive for low cost and high efficiency.
- Must consider low-income users (affordable service) and financial situation of incumbents.
- Transit is a private activity and must remain private.
- Municipal role: planning and management of transit service (not operation).

These guidelines showed the expectations of the decision-makers and allowed the technical staff to define scope boundaries from the start of the project. However, these guidelines also generated constraints, especially for technology. By not allowing subsidies for operation, and defining the inclusion of the incumbents, the technology alternatives were indirectly narrowed to diesel vehicles. Nonetheless, the FS includes an analysis of technology alternatives (articulated diesel buses, articulated trolleybuses, LRT and subway) and concludes that articulated diesel buses are the preferred option. In terms of alignment and size, the plan followed the existing corridors patterns (demand and street network) and a rational process of analysis without significant influence from external factors.

The plan also included a new institutional framework to organize the system and one key element is the creation a special purpose vehicle (SPV) to plan and supervise the operations. The municipality proposed this entity as a private technical institution with autonomy and technical capabilities, and highlights the benefits of a private institution, such as flexibility in decision making, faster processes, community representation and higher independence from political intervention. This institution takes the form of a non-profit organization whose main objective is the “wellbeing of society through the transportation of passengers” with four main tasks: planning, management, regulation and control of Metrovia.

The governing body of the SPV is composed of the municipality, the National council of Transit and a civic group. This composition contrasts with the private nature of the SPV. However, the board of directors includes representatives of the above institutions and also from the chamber

of commerce, the chamber of construction, the university's council, the association of banks (creditors for the consortiums), the federation of transport operators and a representative of the community. This particular arrangement of stakeholders is important due to the diverse nature of the representatives and also for the absence of the private consortiums for the construction or operation of the system. Furthermore, a fiduciary agent and private contractor are in charge of fare collection and operations design respectively and function independently from the municipality and the bus operators.

### **3.3.1 T1 “Guasmo – Rio Daule”**

The first trunk line, T1, is a system spanning 15.8 km, with central stations, one lane per direction and 40 articulated buses. This line has two integration terminals and 35 intermediate stops (400 m average distance) with pre-board fare collection, at level entry, similar to the BRTs in Quito.

The financing agreement was signed in November 2002. The feasibility study for this project estimated an initial investment of 38.2M USD for the first trunk line, including vehicles at 11.9M. The daily ridership was estimated at 140,000 passengers (Arguello, Medina, von Buchwald, Paranhos, & Arias, 2004) (von Buchwald, 2007). The daily demand was reported at 140,000 passenger for T1 (BRT Centre of Excellence; EMBARQ; IEA; SIBRT, 2017) (2013). The institutional information from 2011 indicates a cost of infrastructure of 2.2M USD per km (15 km span).

This project and subsequent T3 and T2 have a similar approach for the execution: a traditional DBBMP. The execution was divided in major work groups (lanes, terminal stations, intermediate stations). The level of disaggregation within the traditional DBB is lower when compared to the projects in Quito, with larger contractors in charge of aggregated workgroups (e.g., segregated lanes, intermediate stations).

A consortium of historic operators was formed to provide the service and acquire the articulated buses. The contract was signed in 2005 with consortium “Metroquil” for a 12-year period. Operations started in July 2006 (von Buchwald, 2007).

### **3.3.2 T3 “Bastion Popular – Centro”**

The second trunk line, T3, is a system spanning 15.5 km, with central stations, one-lane per direction and 60 articulated vehicles. T3 was executed before T2 because the North-West side of the city was growing rapidly as a result of invasions of public land (i.e., informal housing). Hence, it was a priority to provide a transportation system to this particular area ahead of schedule. The feasibility study for this project estimated an initial investment of 34.29M, including vehicles at 9.1M.

The daily ridership was estimated at 200,000 passengers (von Buchwald, 2007). This system was expected to operate by the end of 2007 (von Buchwald, 2007). The daily demand reports (BRT Centre of Excellence; EMBARQ; IEA; SIBRT, 2017) indicate 170,000 passenger for T3 (2014). The cost of infrastructure was reported by Metrovia in 2011 at 1.48M per km (15.5 km span). A consortium of historic operators was formed to provide the service and acquire the articulated buses. The contract was signed in 2007 with consortium “Metro Bastion” for a 12-year period and operations started in May 2008. The inauguration date of this line fits in the schedule of the feasibility study that stated the implementation each trunk line within a 2-year frame.

### **3.3.3 T2 “Venticinco de Julio – Rio Daule”**

The third trunk line, T2, is a system spanning 13.1 km, with central stations, one lane per direction with some sections that allow overpass at intermediate stations and 56 vehicles. The feasibility study estimated an initial investment of 87.58M including vehicles. However, the budget also includes two major overpasses for the city (50.78M). Without considering the overpasses, it was estimated at 36.8M (vehicles at 9.2M). The daily ridership was estimated at 120,000 passengers. This system was expected to operate by the end of 2008 (von Buchwald, 2007). A consortium of historic operators was expected to provide the service and acquire the articulated buses.

The start of work for this trunk line was postponed by the municipality. In July 2011, the civil works started (Guayaquil, 2011), the contract with consortium Metro Express was signed in 2012, and operations started in February 2013. The cost of infrastructure was reported at 4.18M USD per km (13.1 km span). The daily demand was of 144,000 in 2014 (Metrovia, 2015).



### **3.3.4 T4-T7**

Political conflict played a major role in the non-implementation of the four remaining trunk lines. The data collected revealed that the principal reason for not implementing the remaining trunk lines was political opposition. The central government (opposed to municipal) provided support for incumbents whose routes were affected. This opposition also meant difficulties for the sovereign collaterals necessary for international financing, due to the procedures of international financing that require national government warranties. Conversely, the national government was aligned with the municipalities of Quito and Cuenca and offered major support for their rail projects. This new wave of technology selection dominates rapid transit projects from 2009 to 2015.

## **3.4 Group C: Rail Projects Quito and Cuenca 2009 to 2015**

### **3.4.1 Subway Line 1**

The Quito Subway Line 1 project can be traced back to the municipal campaign of early 2009, where it was promoted as a solution for worsening transit and traffic issues. In October 2009, the cities of Quito and Madrid signed a cooperation agreement to develop a "transportation system with subway characteristics" (Publicas & Madrid, 2011), sponsored by Ecuador's national planning agency. In 2011, a contract with Madrid's Subway company was signed for the "Studies for the conceptual design of an integrated transport system and the feasibility of the first subway line". The studies show a new vision of the city transit system, based on a subway line and a complete restructuring of the bus network, in part to feed the proposed subway line.

This is the first planning effort that incorporates household travel survey data into the travel demand model. The forecasted ridership for 2016 (expected operation as per the FS) was 18,547 pphd and was projected to increase to 29,746 pphd by 2046. The technical team recommended a subway considering the forecasted ridership and also to induce mode shift and cope with increasing motorization in the city. As of today (April 2021), the expected start of operations is set for 2022 (six-year delay).

The FS led by Madrid's Subway company did not include analysis of previously developed technology and alignment alternatives, for example expanding the capacity of existing corridors with LRT (as proposed for Trolebus in 1991 by capitalizing on the existing electrical infrastructure) or increasing BRT capacity with double articulated trolleybuses, or the implementation of the parallel corridors identified in the study of 1991, which would appease demand in the central line. A subsequent ad-hoc study (environmental impact) presented a more detailed, but still qualitative, evaluation of alternatives (GESAMCONSULT, 2012) that arrives at the same conclusion (subway).

For the alignment, the FS outlined three preliminary alternatives. Each alternative was tested for ridership and the one with the highest ridership was recommended. The alignment of the subway followed closely the Trolebus route in the north and south sections. This was the main argument to recommend the elimination of this BRT. However, this recommendation overlooked a fundamental difference in area coverage due to distance between stops in the two systems and the elimination of Trolebus was subsequently revised. The scope of the subway was limited by the cap of 1.5 billion USD that was assigned to the project, with 50% municipal and 50% national funding. As of April 2020, the implementation continues, and the budget has surpassed 2.3 billion USD (i.e., 109 million USD per km).

### **3.4.2 Tranvia**

The Tranvia project in Cuenca can also be traced back to the municipal campaign of early 2009. The incumbent mayor had developed a study for a BRT trunk line, but the candidate offering rail (with support from the national government) was elected in late 2009 and discarded the bus-based option.

The FS follows a traditional structure and starts with the goal to “Implement a transportation system of first level in the shortest time possible”. The initial exploration of alternatives considers three potential alignments and recommends the one with highest ridership. In this alignment, six technologies were evaluated (buses, “BRT light”, “BRT full”, LRT, heavy rail and monorail) with a multi-criteria decision analysis (MCDA). However, the evaluation was

based on general features of each technology and not specific analysis of the characteristics of the alternatives. For instance, ranges of capital costs, speed, and urban impacts were used to support the selection of LRT. A BRT option with diesel buses was discarded mainly due to emissions concerns. Trolleybuses were not analyzed in this study. This is the first study where a "do nothing" alternative was evaluated (Artelia, 2011). The estimated ridership was 100,000 passenger per day and the project started operations in May 2020 under a public company (i.e., municipal operation). The total cost of the project was projected to be 178 million USD, however the total costs reached 277 million USD (25.2 million per km.)

Rail projects for urban rapid transit were viewed as unaffordable by the technical teams until 2009. The active participation of the central government played a key role in their proposal, probably supported by an unusual national budget surplus fueled by high oil prices. After the planning processes of 2009-2010, a new wave of technology for rapid transit appears: urban gondolas.

### **3.5 Group D: Urban Gondola Projects in Guayaquil and Quito (2015-2018)**

In general, gondola projects are suitable for alignments where other technologies are not feasible due to topography (e.g., steep grades). In such cases, the technology depends on the selected alignment (i.e., technology and alignment are not independent). However, for the gondola projects in Ecuador, other technologies were feasible in both planning processes for sections of the chosen alignment, as the transit service is currently provided by buses. In these two cases, a relevant advantage of the gondola technology resides in not requiring the utilization of the existing road network (i.e., gondolas do not decrease the road capacity by utilizing lanes for BRT or LRT alternatives), as shown in Figure 3-5.



**Figure 3-5 Aerovia project in Guayaquil**

Source: <https://www.primicias.ec/noticias/lo-ultimo/aerovia-conquista-transporte-aire-alcaldia-guayaquil/>

### **3.5.1 Quito Cables**

The gondola projects in Quito were also born out of political campaigns (late 2014). Four lines were studied, and contractual documents show a direct request to analyze gondola lines, hence promoting an ex-ante definition of technology.

The planning (feasibility stage) was divided into five sequential contracts: 1) Feasibility study (only for Cumbaya line), 2) Preliminary study for implementation, 3) Demand study, 4) Economic study, and 5) Technical assistance; these last four contracts included all four lines. This is the only planning process with a subdivision of analyses among different consultants. All other planning processes developed the studies in one bundle (i.e., using one consultant or were internally developed).

The second study uses a preliminary demand estimate and recommends further studies but develops a very detailed alignment. It focuses on the physical possibilities of implementing the lines (e.g., topography). No analysis of alternatives for technology was found in any of the studies, which confirms an ex-ante definition of technology.

The preliminary demand estimate and alignment conditioned the subsequent studies to one alignment and the initial contracts to one technology. The daily estimated ridership varied between

8,600 passengers for the most frequented line to 2,100 passenger per day. The total costs were estimated at 402 million USD (17.3 million per km) for the four lines.

### **3.5.2 Aerovia**

The planning for Aerovia started in 2015 with a FS that required the analysis of a “aero-suspended system”. This municipal definition constrained the technology for the transit system to cable systems of different characteristics (e.g., single cable, tripe cable). Moreover, the municipality also steered the project towards a Public Private Partnership (PPP) from the start. The guidelines for the PPP outline a partial public participation in the initial investment complemented by the private sector and exclusive private operation for thirty years (the first of its kind in Ecuador: 115 million USD were municipal investment and 19 million USD private investment).

The decision-makers aimed at transferring demand risk to the private sector as well as detailed design, operation and maintenance, in hope of aligning the inherent interest of the private sector with efficiency and quality of service. This risk transfer also implied that the demand was crucial for the model’s success, therefore alignment was of high importance.

The FS presented the characteristics of different cable systems (e.g., monocable, bi-cable, tri-cable) and a thorough analysis of over thirty alignment alternatives, in search of the highest demand line. It concludes that the best alignment is not within the city, but connects Guayaquil Central Business District (CBD) with its neighbor, Duran, across the Guayas river. In 2015, these two cities were connected by a single and heavily congested 3.5 km bridge. This bottleneck increased travel times significantly and their analysis showed the highest demand was for this alignment. The alignment was mostly determined by demand and local conditions as the technology requires heavy investments (stations) for non-linear configurations (i.e., additional stations). The scope of the project was limited mostly by finances. At 23 million USD per km, gondolas place a heavy burden on a developing city. The estimated demand for the first year of operations was 23,800 passengers per day, with a projection of 36,000 for the seventh year. This project started operations in December 2020 amid the Covid-19 pandemic.

## **3.6 Group E: BRT in Quito 2015**

### **3.6.1 Trole Norte**

In 2015, a new BRT planning process started in Quito: for the north extension of Trolebus. The FS shows the analysis of different technologies and project scopes. The alignment was mostly influenced by the local conditions that left only one viable alternative. The network configuration had only one road capable of providing the necessary cross-section and continuity for most of the alignment, as reflected in the Terms of Reference (ToR) requirements. For the remaining 2 km, after assessing detailed potential alternatives, the FS proposed a new road for the North terminal access.

The analysis of technology defines trolleybuses as the preferred technology after studying diesel and electric battery buses and discards rail configurations due to large gradients in the north section (i.e., 15%). Trolleybuses presented an advantage for vehicles to transition smoothly from the existing electrified trunk line (Trolebus) to the extension. The evaluation also includes a preliminary financial assessment of the capital costs based on fleet requirements.

This process recently finished the detailed design phase and concludes that the main Trolebus trunk line can remain fully operational in the future. This contradicts the analysis from the Subway Line 1 project, which recommended its elimination, signaling a new direction of the transit vision for the city, yet again. This project estimated a daily ridership of 124,000 passengers and the budget of 82.3 million USD (8.2 million USD per km).

Table 3-1 summarizes the detailed project features for the planning processes described in this section.

**Table 3-1 Project features for planned rapid transit projects in Ecuador (1991 to 2018)**

Group	Quito BRTs			Guayaquil BRTs				Rails		Urban gondolas					Quito BRT
Planning process	1	2	3	4				5	6	7	8				9
Project name	Trolebus	Ecovia	CN	T1	T2	T3	T4/T5/T6/T7	Subway line 1	Tranvia	Aerovia	Pisuli/Roldos	Centro	Sur	Cumbaya	Trole Norte
Location	Quito			Guayaquil				Quito	Cuenca	Guayaquil	Quito				Quito
Year of initial planning	1991	1995	2000	2002				2009	2010	2015	2015				2015
Technology	Articulated trolleys (Trolebus) / Articulated diesel buses							Subway	LRT	Urban gondola					BRT
Span (km):	11	9	11	15	14	15	12-15	21	11	4.1	4.1	1.2	4.1	7.9	10
No. of stations	18	18	14	36	23	32	24-36	13	21	4	4	3	3	4	21
Station spacing (km)	0.4	0.5	0.8	0.4	0.5	0.4	0.5	1.6	0.5	1.0	1.0	0.4	1.4	1.9	0.5
Peak hour estimated ridership (000s pphd)	10.2	6.5*	N/A	7.0	13.0	11.0	N/A	18.5	4.0	1.8	1.6	0.4	0.7	N/A	5.6
Daily estimated ridership (000s pphd)	123	140*	400	140	220	120	N/A	377	100	36	8.6	4.2	2.1	4.1	124
Implemented	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	No	No	No	No
References	(C. Arias et al., 1991; D. Hidalgo & Graffiaux, 2005)			(Arguello et al., 2004; "Fundación Metrovia   Sistema Integrado de Transporte Masivo Urbano de la ciudad de Guayaquil," n.d.; von Buchwald, 2007)				(Empresa Metro de Quito, 2012; GESAMCON SULT, 2012)	(Artelia, 2011)	(Consultores A&V, 2015)	(DCSA ingenieur conseil, 2015; INECO, 2015; Pontificia Universidad Católica del Ecuador, 2015)				(Quito, 2015)

000s pphd: thousands of passengers per hour and per direction

\* Forecasted ridership was met, but initially the corridor operated with a limited municipal fleet, due to incumbent's financing inability.

From 1991 to 2018, three cities (Quito, Guayaquil and Cuenca) developed nine planning processes, that encompass eighteen projects. In Guayaquil, the Metrovia planning process encompasses seven BRT trunk lines and in Quito, the Quito Cables process includes four urban gondola projects. These eighteen projects were planned and implemented in five distinct groups, characterized by timeframe, location and technology. Their planning processes were affected by different factors: technical (i.e., local conditions and demand), social, financial, political. However, the relative importance of the influence of these factors in the project features is unclear, as well as the effects on the implementation or archive of the projects (i.e., the barriers for implementation). Chapter 4 presents the quantitative analysis of factors that affected the planning process (i.e., the design of the systems) and Chapter 5 a quantitative analysis of the barriers for the effective implementation of these systems.



## Chapter 4

### **The Design: Factors that Shape Rapid Transit Projects**

In practice, the process of transportation planning is shaped by more than technical factors. This chapter analyzes how different factors (i.e., demand, local conditions, financial, social and political) have influenced all of the rapid transit projects in Ecuador over the past three decades by evaluating their relative significance on each system component (i.e., alignment, size, and technology). The purpose of quantifying the relative importance is to understand the extent of the impacts of different factors on the rational planning process. This information is key to comprehend how the systems' components were affected and how the ultimate design was achieved.

This chapter presents the only comprehensive analysis of all planned rapid transit projects in Ecuador to date and is based on quantitative and qualitative data collected specifically for this purpose. The congruence and deviations between theory and practice are then characterized, before recommendations are made based on identified best-practices in these planning processes. The remainder of this chapter is organized as follows. The next sub-section explains the methodology: a mixed-method of multiple case comparative analysis and Analytical Hierarch Process (AHP). The following sub-section presents the results of the reconstruction of the decision-making processes and quantification of the relative significance of the factors. The subsequent sub-section discusses the factors' evolution and the gap between theory in practice, along with the limitations of the research. Finally, conclusions specific to the planning process are presented.

#### **4.1 Methodology**

To consider the relevance of the development and context for each project's planning process, this part of the research uses a multiple-case methodology to derive cross-case comparisons, which follows the theoretical framework described by Yin (2014). The scope includes all the rapid transit projects planned from 1991 to 2018 in Ecuador and aims at deriving findings on the basis of

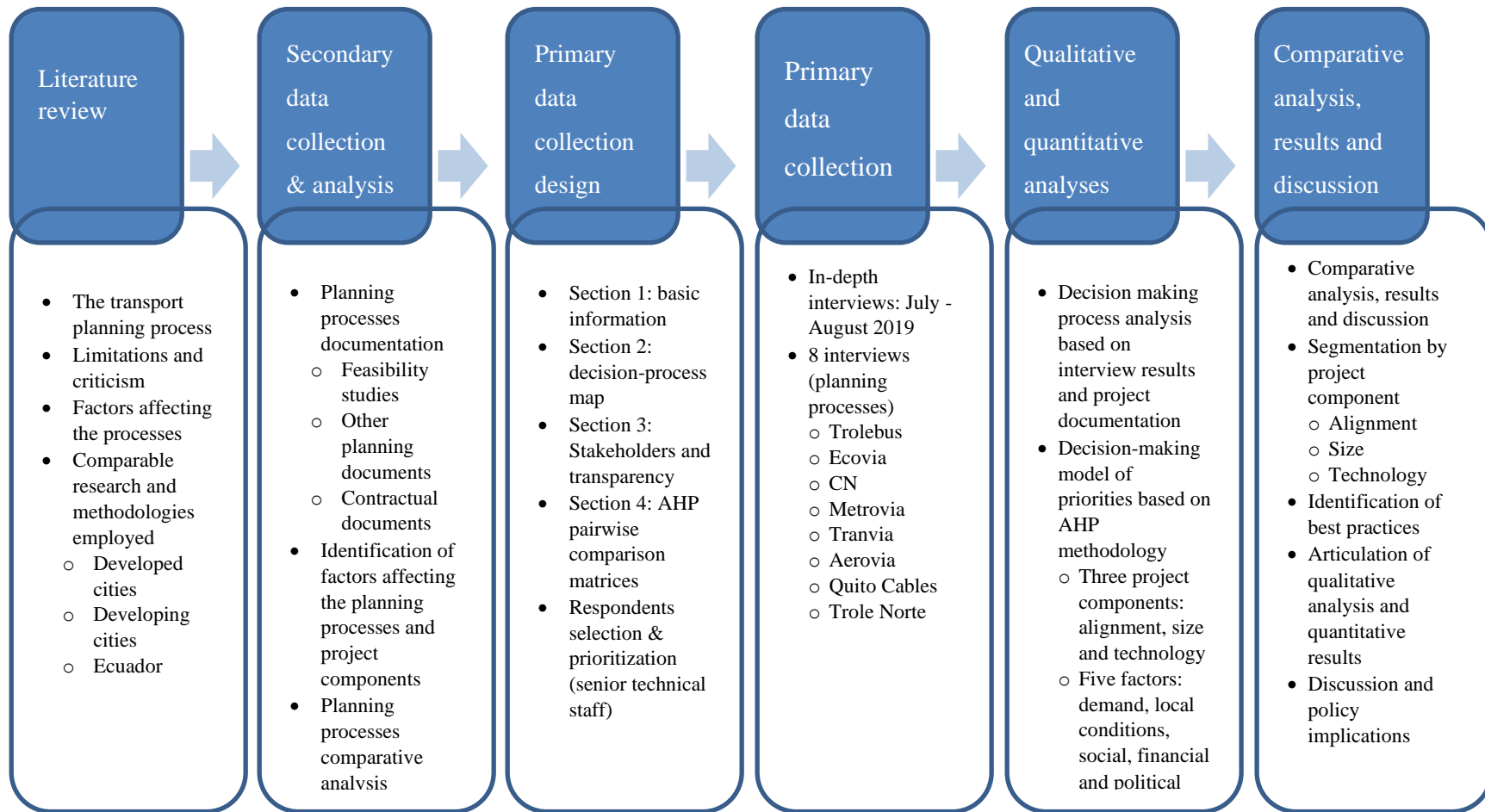
examining nine cases (i.e., planning processes) with similar settings: social, economic and institutional characteristics. Hence, this study considers not a sample, but all the cases, which allows observation of the evolution of the factors and also controls for variations that can stem from jurisdictional changes (e.g., legislation in other countries). Figure 4-1 depicts a summary of the research framework.

First, a review of the project documentation (i.e., feasibility studies, contractual and public documents and existing literature) was conducted to systematically analyze and compare the projects and their contexts, components (i.e., technology, alignment, size) and to establish the factors (internal and external) affecting the projects. This analysis was partially presented in Chapter 3 and is further elaborated in this chapter. In addition, the ranges of demand estimates were carefully analyzed as key elements that permitted the consideration of technology alternatives (e.g., BRT vs. LRT).

These initial analyses were the basis for the design of an in-depth interview that aimed at reconstructing the decision-making process through backward-mapping (Elmore, 1979), contextualizing the projects and collecting information to derive pairwise comparison matrices to evaluate the rationality of the projects' design. For this, the input of senior members of the technical teams were the key sources of data. These practitioners had a holistic perspective and in-depth knowledge of their project, as well as interaction with the political, social and financial factors affecting it. One interview for each project was conducted to maintain analogous data among all projects. Three considerations were made for this approach: 1) The extensive timeframe of the projects (30 years); 2) The comprehensive perspective of senior technical staff that permitted the evaluation of the factors; and 3) The possibility of identifying inconsistencies in the judgements with the Analytical Hierarch Process (AHP) methodology. In addition, the quantitative results were assessed and confirmed with the reconstruction of the decision-making process, and with the project documentation (i.e., contracts, studies, reports).

The respondents were selected by prioritizing the highest-ranking staff member in each project, ranging from Project Managers to Planning Agency Directors. Eight in-depth interviews (corresponding to eight planning processes) were conducted between July and August 2019 in Quito, Guayaquil and Cuenca. The interview guide included four sections (see Figure 4-1) with

forty-four questions and four pairwise comparison tables (see Appendix A). The first three sections aimed at reconstructing and contextualizing the decision-making process. In spite of several efforts, the interview for Quito's rail project could not be obtained. The following sub-sections present a more detailed review of the methodological approach to reconstruct the decision-making process and the evaluation of the relative importance of the factors affecting each project component.



**Figure 4-1 Research framework flowchart for the design processes**

### **4.1.1 Mapping the Decision-Making Process**

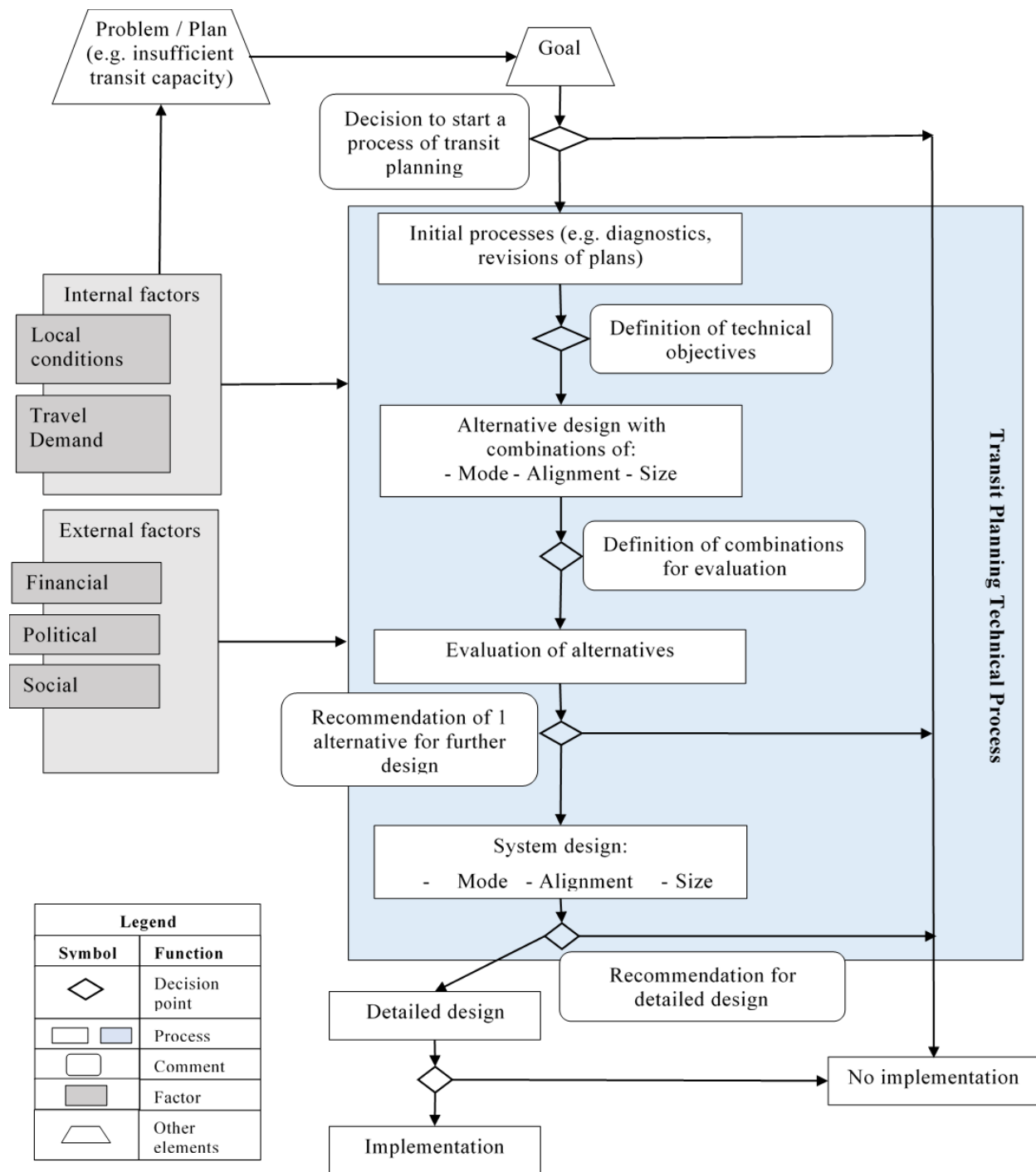
Given the complexities and individual characteristics of each planning process, the case study approach is the appropriate tool for the analysis (Yin, 2014). This approach allows an in-depth analysis on a case-by-case basis. Previous research on decision making of highway projects and for BRT guidelines also utilizes case study methodology to explore specific projects individually (Brach, Ann; Andrie, Stephen; Allen, Cynthia; Campbell, Kenneth; Coleman, 2010 ; Levinson, Zimmerman, Clinger, Rutherford, et al., 2003).

Two major sources of information are considered in this stage of the research: the project's public records and technical team inputs. The data for the planning and design of the systems was extracted from the feasibility study of each project and available public records.

Three major project planning components are the focus of this analysis: the system's technology, alignment and size (Vuchic, 2005). The decomposition of the system permits greater precision in the examination, especially with respect to the selection of technology. The technology of the system refers to the mode utilized for transportation. For the projects under study, four technologies were identified: BRT, LRT, Subway, and urban gondola.

Five planning stages were identified with the same method: project objectives, alternative design, alternative evaluation, system design. This last component includes the final decisions regarding technology, alignment and size for the system. A fifth stage encompasses the detailed engineering design and implementation and is considered the result of the previous four. Five key decision points are recognized in this process and each decision point corresponds to an element of the planning procedure.

Figure 4-2 shows a conceptual overview of the transit planning process that includes the internal and external factors, the key processes and the main decision points.



**Figure 4-2 Transit planning process and factors**

The input from the technical team was collected through in-depth interviews (see Appendix A). This technique is designed to collect the perspective of individuals with a high level of

knowledge in a subject. The method provides not only valuable data, but also the corresponding interpretation. It includes a structure to guide the interview, but also allows flexibility to cover topics that arise as the interview progresses (also known as content mining). The interviewer can ask for response expansion or clarification and the interviewee can request clarification of questions. This allows the exploration of more complex issues (Ritchie, Lewis, McNaughton Nicholls, & Ormston, 2014).

Audio taping was used during interviews to assist the analysis. In order to generate an environment that did not compromise the interviewees or hinder certain responses, their identity remains undisclosed. Therefore, to ensure confidentiality throughout the process, respondents were identified with numbers. This procedure is comparable to the one used by Flyvbjerg to analyze costs and time overruns for large infrastructure projects, where the interviews to consultants and technical teams played a key role in the research (Flyvbjerg, 2009).

A graphic representation of the concept model for the planning process was used during the interviews to guide the mapping procedure. This method is similar to the one used by the Framework for Collaborative Decision Making on Additions to Highway Capacity (Brach, Ann; Andrie, Stephen; Allen, Cynthia; Campbell, Kenneth; Coleman, 2010).

The decision-making process was reconstructed starting with the final decision outcome and work backwards from this point. This procedure is also known as “backward-mapping” (Elmore, 1979) and has been used to reconstruct prior policy decisions. It allows a more precise identification of the factors that affected each decision.

These processes returned a detailed reconstruction of the decision-making process for the planning stage for each of the projects under study. The objectives of this stage are twofold: to obtain the specific elements that led to the selection of the alignment, technology and size of the selected alternative; and to identify the barriers and key success factors of each project.

These initial inputs regarding the external forces that affected the project’s outcome are complemented with a quantitative analysis. For this purpose, a technique that can measure the relative importance of the factors that affect the planning process was utilized.

#### 4.1.2 Decision-Making Model: Relative Importance of Factors

The pairwise comparisons in the fourth section of the survey were used to develop a decision-making model based on the AHP (Saaty, 2005). AHP was selected for this analysis after reviewing the MCDA approaches and models with regards to the objective of assessing the impact of factors in the planning processes. In the area of multi-criteria decision analysis, there are three main approaches: weighted additions, rankings and goal programming. The former (i.e., weighted additions) is appropriate to evaluate the relative importance of the factors in the decision-making process. In this subfield, a multitude of models have been developed (e.g., multi-attribute utility theory), however, for this research it was necessary that the method included three main characteristics: first, it allows the participation of the technical staff of the projects; second, it provides cardinal weights for the factors; and third, it allows for the evaluations of the congruency of the responses of the technical teams. AHP complied with these characteristics. In addition, it has been used extensively in prior civil engineering research.

This method of relative measurement permits researchers to synthesize judgement, rank intangible criteria, create hierarchical levels of analysis and check the consistency of judgements. The respondents evaluated the relative importance of the factors with pairwise comparisons (e.g., two factors at a time: how much more or less important was the social factor than the financial factor) for each project component. Through this method, the respondent is able to make more accurate judgements vis-à-vis intangible criteria (i.e., factors). This is the basis to form a pairwise comparison matrix, from which a vector of priorities can be derived. Brunelli (2015) presents a detailed review of the AHP procedures, which are briefly outlined here.

The concept of the vector of priorities is central to AHP, as it represents an order of magnitude among alternatives or criteria as the most important condition. From this condition, AHP states that the vector in question must preserve the ranking and thus remain invariant under multiplication of a given constant (Saaty, 2003a). From a spatial perspective, it can be interpreted that assuming conditions remain equal, the system under study (matrix) can increase or decrease its size, but must preserve its fundamental properties (proportions). The vectors that remain invariant in matrix transformations are eigenvectors and are associated to specific eigenvalues.

For the pairwise comparison process, AHP uses a relative scale, called “The Fundamental Scale” (see Table 4-1). This scale aims to measure the relative importance of one element vis-à-vis another element in one specific criteria. This result is denoted  $a_{ij}$ , where  $i$  and  $j$  are the



alternatives in comparison. The methodology implies the existence of reciprocal entries, meaning that if  $a_{ij} = 3$ , then  $a_{ji} = 1/3$ . For instance, if the level of comfort of vehicle A is considered to be moderately more important (equivalent to 3 in the scale for AHP) than the level of comfort of vehicle B, then  $a_{ij} = 3$ , and reciprocally  $a_{ji} = 1/3$ .

**Table 4-1 Fundamental scale for AHP**

<b>Intensity of importance</b>	<b>Definition</b>	<b>Explanation</b>
1	Equal importance	Two activities contribute equally to the objective
2	Weak importance	
3	Moderate importance	Experience and judgment slightly favor one activity over another
4	Moderate	
5	Strong importance	Experience and judgment strongly favor one activity over another
6	Strong plus	
7	Very Strong or demonstrated importance	An activity is favored very Strongly over another; its dominance demonstrated in practice
8	Very very Strong importance	
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation

The process collects the pairwise comparisons between alternatives for each corresponding criteria. The result is a matrix of pairwise comparisons  $A^{(x)}$  that presents the relative importance of the two alternatives in analysis with respect to one specific criteria  $x$ , where the superscript  $(x)$  identifies each pairwise comparison matrix for that criteria. Thus, the analysis requires  $x$  number of matrices corresponding to the number of criteria in the hierarchy and one additional matrix of pairwise comparison to assess the relative importance of each criterion.

This approach increases in complexity as the hierarchy system expands. Equation 4-1 presents the composition of *Matrix*  $A^x$

$$A^x = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix} = \begin{bmatrix} w_1/w_1 & \cdots & w_1/w_n \\ \vdots & \ddots & \vdots \\ w_n/w_1 & \cdots & w_n/w_n \end{bmatrix} \quad (4-1)$$

where  $a_{mn}$  (intensity of importance) represent the entries of Matrix  $A^{(x)}$  and are the result of the pairwise comparisons. The entries  $a_{mn}$  of the matrix represent ratios between two elements, therefore they can be expressed in the form of  $w_i$  and  $w_j$  where  $w_i/w_j$  is the weight (intensity of importance) of alternative  $i$  with respect to alternative  $j$ .

For each matrix a vector of priorities is derived. AHP uses the concept of principal eigenvector for this purpose. In linear algebra, eigenvectors are vectors of linear transformation (e.g., matrix multiplication) that change only by a scalar value when the linear transformation is applied. The scalar value is known as the eigenvalue. The eigenvector can be viewed as a “mirror” of the  $A(x)$  matrix, that retains its properties (proportions). However, its most important feature is the form (i.e., vector) that allows derivation of the weights for each criteria after normalization.

The core relationship between the pairwise comparison matrix and the vector of priorities takes the form of Equation (4-2):

$$AW = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix} \begin{pmatrix} w_1 \\ \vdots \\ w_n \end{pmatrix} = \begin{pmatrix} \lambda w_1 \\ \vdots \\ \lambda w_n \end{pmatrix} = \lambda w \quad (4-2)$$

where  $A$  is the matrix of pairwise comparisons,  $w$  is a vector of priorities (unitless), and  $\lambda$  is a constant or scalar (unitless). The relationship implies that the vector  $w$  is an eigenvector and  $\lambda$  is the corresponding eigenvalue.

It is important to note that there are multiple methods to derive eigenvalues and eigenvectors for a given matrix. One of them utilizes the identity matrix  $I$ , a constant  $\lambda$  (scalar), and a vector  $W$ . Equations 4-3, 4-4, 4-5 and 4-6 show the utilization of the identity matrix  $I$  as the first step in the eigenvalue calculation.

$$AW = \lambda W \quad (4-3)$$

$$AW - \lambda W = 0 \quad (4-4)$$

$$AW - \lambda IW = 0 \quad (4-5)$$

$$(A - \lambda I)W = 0 \quad (4-6)$$

The solution of  $W = (0, \dots, 0)$  is excluded since it will not provide a meaningful vector of priorities, thus the problem can be formulated by setting the determinant of  $(A - \lambda I)$  to zero, which is a characteristic polynomial. Equation 4-7 shows the determinant of  $(A - \lambda I)$ .

$$\text{Det} \left\{ \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix} - \lambda \begin{pmatrix} 1 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & 1 \end{pmatrix} \right\} = 0 \quad (4-7)$$

The results are the eigenvalues and are sorted from smallest to largest (absolute value) to find the maximum eigenvalue. Saaty (2001) proposes to utilize the maximum eigenvalue ( $\lambda_{max}$ ) to derive the principal eigenvector (also known as the principal component). A more detailed explanation of the AHP procedure utilized in this research is presented in Appendix D (AHP General Procedure Application).

The process of deriving the priorities vectors from each matrix has been subject of extensive research and hence several methods exist (Brunelli, 2015). Saaty and Vargas (2001) propose to derive the vector of priorities based on the principal eigenvalue (largest absolute eigenvalue) as the only valid solution.

Saaty and Vargas (2001) state that the pairwise comparison matrices are inconsistent and call the entries “perturbed” values of matrix A, since the reciprocal values are not exact (forced reciprocals) and neither are the judgements that are used to fill the matrix (sometimes intransitive judgements). These judgements are considered approximations of the optimal matrix. The optimal matrix is one with the exact judgements for each comparison.

The approach to solve this problem consists of raising the matrix to a large power, where the principal eigenvector solution is stable (presents minimal fluctuations). In other words, raise the matrix of pairwise comparison  $A^{(x)}$  to the  $k^{th}$  power, where the derived vector suffers minimal changes in comparison to the previous iteration ( $k^{th-1}$ ). It relies upon the properties of the Perron-Frobenius theorem (that states a positive matrix has a unique largest eigenvalue corresponding to an eigenvector with positive components) and the power method also known as Von Mises iteration to reach convergence (Clint & Jennings, 1970; Saaty, 1977, 2003b).

Saaty and Vargas (2001) caution the use of alternative methods (e.g., geometric mean) of vector derivation as they may lead to “rank reversal”. This is particularly important in cases where high precision is required, in other words, where the values of the priorities vector are close. This research used the software developed by Saaty (Saaty, 1996) to derive the model results.

In order to confirm the validity of the matrices of pairwise comparison obtained with the AHP scale, a consistency index of the matrix in study (CI), a consistency index of a random-like matrix (RI) and a consistency ratio (CR) are used.

The consistency ratio measures the level of similarity between the entries from the pairwise matrix and a set of matrices filled with random entries. The RI is given in the form of a table for different matrix sizes. Table 4-2 shows the values for squares matrices between 3 and 10.

**Table 4-2 Values of  $RI_n$**

<b>n</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>7</b>	<b>8</b>	<b>9</b>	<b>10</b>
<b><math>RI_n</math></b>	0.5247	0.8816	1.1086	1.2479	1.3417	1.4057	1.4499	1.4854

The index and ratio are presented in Equations 4-8 and 4-9 respectively:

$$CI(A) = \frac{\lambda_{max} - n}{n - 1} \quad (4-8)$$

$$CR(A) = \frac{CI(A)}{RI_n} \quad (4-9)$$

where  $A$  is the matrix in study,  $\lambda_{max}$  is the principal eigenvalue of  $A$  and  $n$  is the number of compared elements. Saaty (2001) indicates that for a given matrix  $A$  the  $CR$  must be under 0.10 to be acceptable, otherwise the entries of the matrix could be considered random.

For this study, the recommended threshold of 0.1 was set for all projects. Hence, the results with over 10% inconsistency were excluded. Cuenca's LRT was the only project that did not meet this threshold.

Five main factors were identified through literature review and analysis of project documentation. Two factors are internal to the project (demand and local conditions) and three are external (financial, political, and social factors). These factors were pre-defined and explained to the interviewees to ensure analogous results:

1. Demand: forecasted ridership;
2. Local conditions: topography, road network and urban characteristics;
3. Political factors: governmental policies, and political decisions or practices that influenced the project;
4. Financial factors: policies, decisions or practices related to the monetary resources available for the project; and

5. Social factors: circumstances, characteristics, or interactions with groups that were affected by the project.

The project components were defined as follows:

1. Technology: vehicles, their mechanical attributes and the right of way (RoW).
2. Alignment: route that the system utilizes between the two terminal stations.
3. Size: physical scope of the system and its components (stations, span of the trunk line).

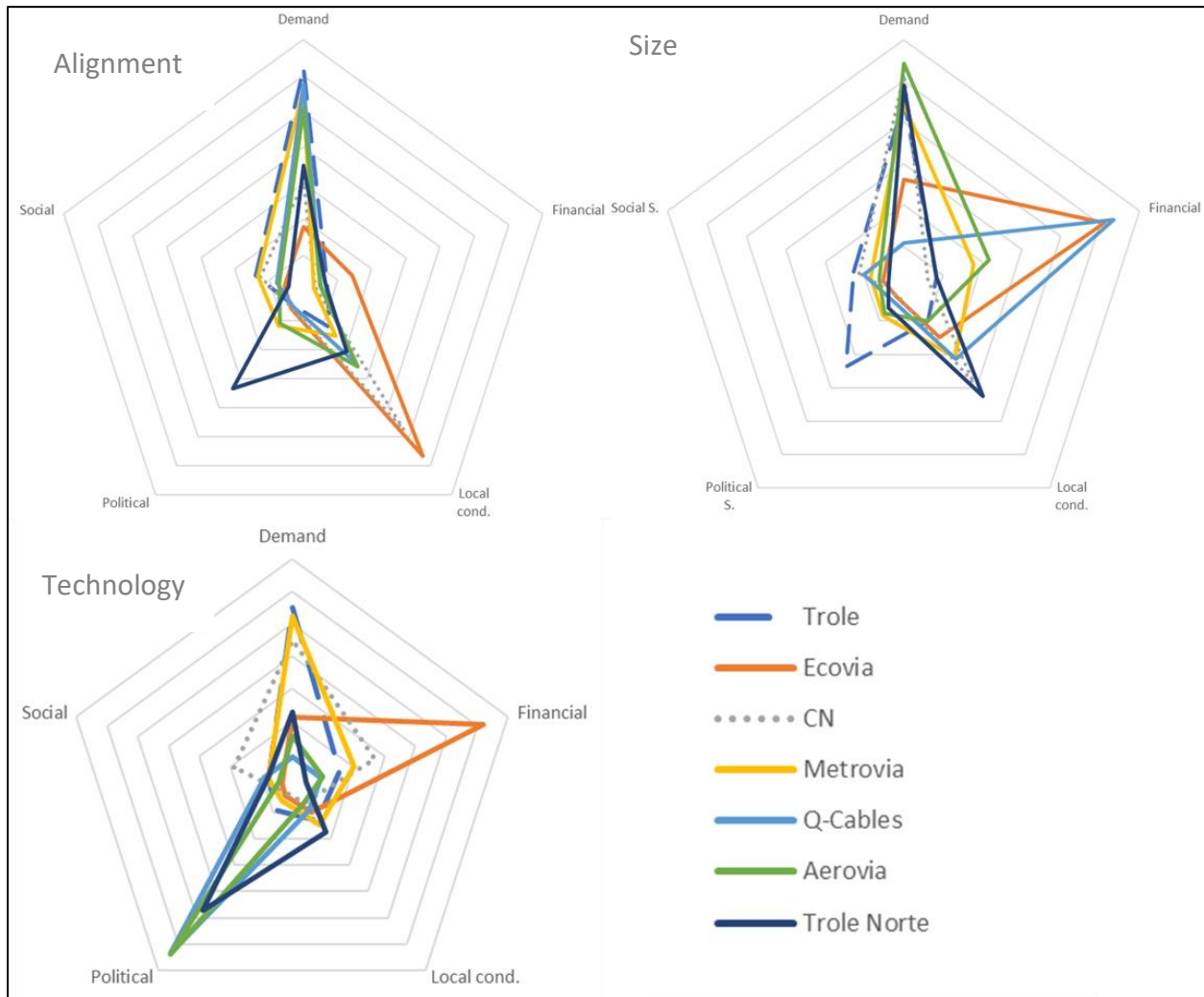
Although further factor and component disaggregation is possible, the induced complexity for the respondents' judgements may outweigh the benefits. The quantitative results are interpreted in terms of signs of direction and orders of magnitude, rather than precise measurements, due to the nature of the responses. The responses were validated by comparisons with the decision process reconstruction completed previously by the respondent (sections 1 to 3 in Figure 4-1), as well as project documentation.

## **4.2 Results and Analysis**

This analysis is segmented by project component (alignment, size, technology) and combines the qualitative (comparative analysis) and quantitative (AHP) aspects to evaluate the factors' influence on the planning processes and the decisions. Although it is possible to review each project individually, for the sake of brevity, the key findings are gleaned by examining the most relevant. Unique project analyses or policies that contributed to a more rational planning process are then highlighted.

### **4.2.1 Evaluation of Factors by Project Component**

The quantitative results show how the project components are subject to different factors and the degree of influence varies drastically. Figure 4-3 depicts the degree of influence of the five factors (demand, local conditions, social, financial and political) for each project component (alignment, size and technology) based on the vector of priorities from the AHP analysis. The center of each diagram represents the lowest influence, which increases towards the outer limits. For instance, in the alignment diagram, local conditions had the greatest influence on the Ecovia project.



**Figure 4-3 Relative significance of factors by project component for rapid transit projects planned from 1991 to 2018**

### **Alignment**

The projects’ alignment studies follow a traditional structure, where different alternatives were evaluated, with the exception of two processes (Ecovia and Quito Cables) that developed only a single alternative (Chapter 6; DCSA ingenieur conseil, 2015). For instance, Aerovia makes a thorough analysis of over thirty alternatives, seeking the highest demand (Consultores A&V, 2015). In contrast, Ecovia studied only one alignment based on a high-demand existing corridor, previously operated by incumbents and that utilized the most suitable path in the road network

(i.e., cross-section and continuity) (Chapter 6). These large variations in the depths of the analysis show the tailoring of studies to specific project requirements, but also discretionary patterns in the level of detail of alternative evaluation.

Demand is the most influential factor for alignment, followed by local conditions. Political, social and financial factors have had limited influence, except for the Trole Norte project, which shows a moderate political influence. This is confirmed by the contractual requirement of studying a BRT for that project. Ecovia and CN in Quito received larger influence from “local conditions”. These projects correspond to a period of economic crisis, where system features were adjusted to existing infrastructure to lower costs. Hence, the financial constraints manifested through the projects’ design adaptation to local conditions (resulting in the first BRT with central stations). Overall, the planning processes for the alignment tend to be driven by internal factors, thus following a rational planning process, with exceptions only due to the economic environment.

### **Size**

In the planning processes, the projects’ sizes were evaluated along with their alignments. Demand was found to be the main factor for the size of the projects. However, finance is highly relevant for Ecovia and Quito Cables. Ecovia’s case is explained by a difficult economic period. For Quito-Cables, this result can be explained by the magnitude of capital costs: \$23M USD/km (compared to \$5.9M USD/km for BRT (Chapter 6), which provoked large budget increases for marginal gains in size, in addition to the financial requirements for the ongoing construction of Subway Line 1, which already placed a heavy burden on the municipality.

Local conditions are more relevant for the size of CN, Metrovia, Quito Cables and Trole Norte, which indicates attempts to further adapt the systems to specific contexts. Trolebus stands out as the only project that shows, to some extent, relevant influence from the political factor. This finding reflects the phased implementation plan, part of a political strategy aimed at limiting the incumbents resistance to the new system implementation. In general, system size also tends to follow a rational planning process, except in negative economic circumstances.

### **Technology**

The analysis of technology is divided in three sections: BRTs, Rail and Gondolas.

The BRTs show different levels of detail for alternative analyses. Trolebus evaluates diesel buses, trolleys and LRT options, including a complete lifecycle cost comparison (this is the only project to present this feature) (C. Arias et al., 1991). For the subsequent BRTs (Ecovia, CN, Metrovia) the level of analysis detail decreases. In these cases, the definition of including incumbents for the operation and vehicle acquisition had a direct effect on the potential technologies, restricting the technology to diesel buses. Nevertheless, in Quito, the incumbent inclusion has two dimensions: financial (budget constrains) and technical (step towards the formalization of the transportation sector in Quito). For Metrovia, the inclusion of incumbents was the result of vision of private participation from the municipality (Chapter 6; von Buchwald, 2007). In the quantitative analysis, Ecovia is the only project that shows a large financial influence for technology explained by financial constraints (i.e., economic crisis). Nonetheless, the relative importance of the financial factor is lower than other internal and external factors for all other projects. This suggests that, under normal economic conditions, the financial factor is not the main factor for technology selection in Ecuador.

The rail systems (Quito Subway and Tranvia in Cuenca) can be traced back to the political campaigns of early 2009, where the national government capitalized on the opportunity to endorse electoral promises. Quito developed a feasibility study (FS) study entitled “Studies for the conceptual design of an integrated transport system and the feasibility of the first subway line” (Metro de Madrid, 2010). A subway was recommended, considering the forecasted ridership (18,547 pphd) (Metro de Madrid, 2010). However, this study did not include an analysis of alternatives, for example expanding the capacity of existing corridors (3 parallel trunk lines with similar alignment) with LRT (as proposed for Trolebus in 1991) or increasing BRT capacity with double articulated trolleybuses. For Tranvia, six technologies were evaluated (buses, BRT, LRT, heavy rail and monorail). Nevertheless, the evaluation was based on general features of standard technologies (i.e., ranges of capital costs, speeds, and urban impacts), rather than the precise inputs of designed alternatives for the corridor (Artelia, 2011). In these two cases, the political factor played a large role in the ex-ante definition of the technology, which is eventually supported by their feasibility studies.

The urban gondolas (Quito Cables and Aerovia) and latest BRT (Trole Norte) show contractual documents with a direct instruction to develop their respective technologies. For Aerovia, an a “aero-suspended system” was required (Consultores A&V, 2015), constraining the



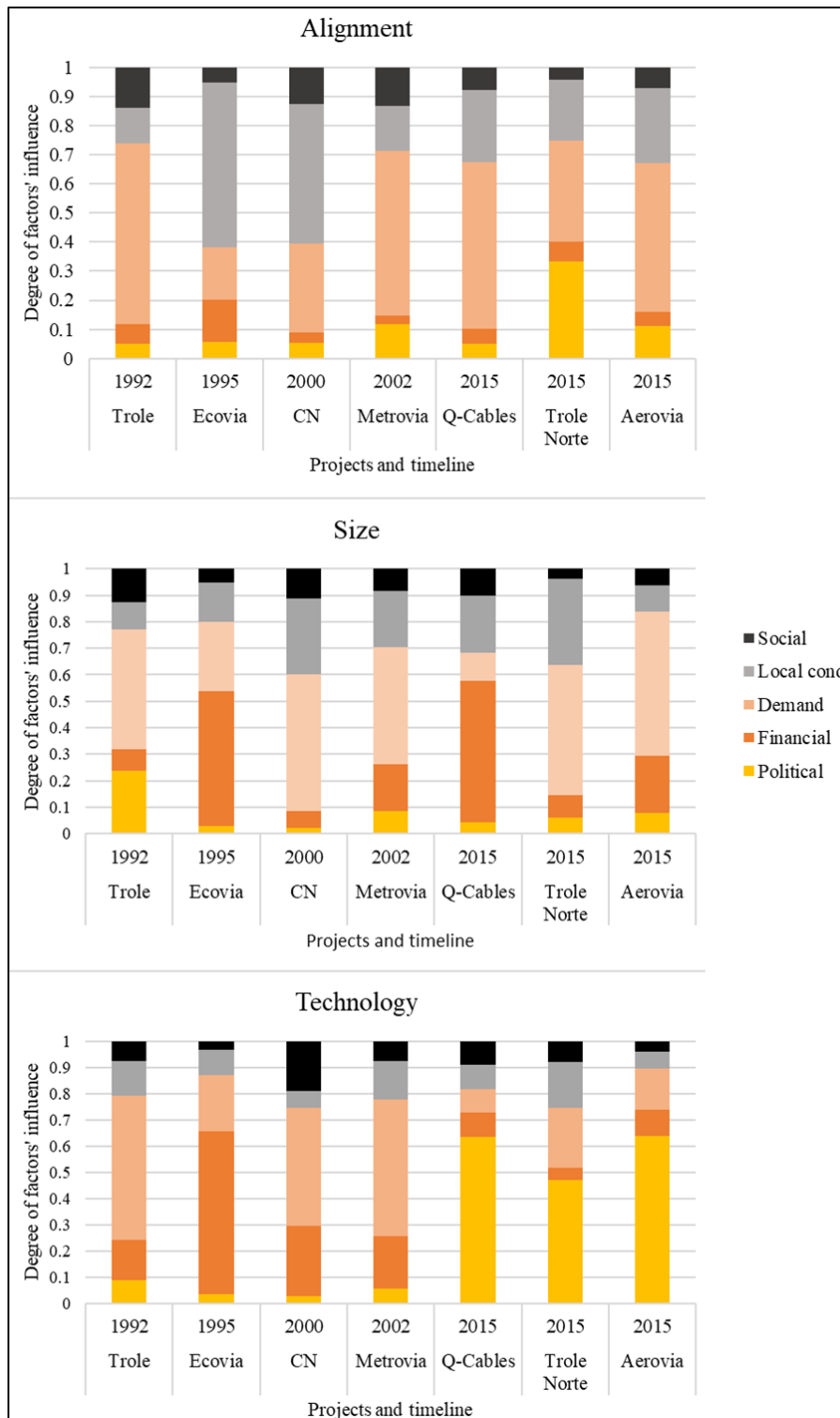
technology to cable systems. Quito Cables and Trole Norte's inceptions were a result of the political campaign of 2014, from which the subsequent contractual documents required the study of "cable lines" and BRT, respectively (DCSA ingenieur conseil, 2015; Quito, 2015). These ex-ante definitions of technology constrained the possibility of analyzing alternatives through contractual instruments, and in the latter case aligns with a political campaign promise. The quantitative results confirm a large influence of the political factor in Quito Cables, Trole Norte and Aerovia. This political influence challenges the rational planning process for system technology.

#### **4.2.2 Evolution of the Factors' Influence Over Time**

A chronological analysis reveals that the factors' influences differ for each component over time (see Figure 4-4).

For alignment, the demand and local condition factors are preponderant, and during economic crisis only local conditions is predominant. Social, financial and political factors have minor importance, except for Trole Norte (political influence). This shows a somewhat steady contribution of factors to alignment influence over time, only disrupted by the economic crisis. Project size presents a more complex picture. First, social and political factors remain of low importance. Second, local conditions show medium importance. Third, the financial factor and demand behave in opposing directions: when the financial factor is of low importance, demand becomes the major factor, and vice versa.

Technology presents steady influences until 2002, driven by the financial and demand factors. Subsequent projects show a significant increase from political influence, replacing the demand and financial factors almost entirely. For Quito Cables, Aerovia and Trole Norte, political influence was the main factor, while the remaining factors had marginal roles (bottom-right three bars in Figure 4-4). The reasons causing this shift to a politically driven technology selection are particularly important for the planning process.



**Figure 4-4 Project planning factor's influence evolution by component**

### **4.2.3 Best Practices**

Four projects (Trolebus, Metrovia, Aerovia, and Tranvia) were found to include a set of analyses or policies that contributed to a more rational planning process.

#### **Lifecycle Economic Analysis of Alternatives: Trolebus**

Trolebus developed a complete economic lifecycle cost analysis for the various technology alternatives (20-year horizon), showing that trolleybuses were preferable to diesel buses (electric motors' advantage). Trolleybuses also required a lower investment compared to LRT. The analysis also anticipated the potential future need to upgrade the system to LRT. This added another advantage to the trolleybuses' electrical infrastructure, which was designed to accommodate this potential upgrade (C. Arias et al., 1991). This was the only project that completed such a detailed evaluation of feasible technology alternatives.

#### **Explicit Decision-Maker Guidelines: Metrovia**

Metrovia is the only project where the decision-makers' guidelines are explicitly stated in the FS (Arguello et al., 2004); the most relevant include:

- Transit service must use resources efficiently, capitalizing on existing infrastructure and vehicles;
- Strive for low cost and high efficiency;
- Must consider low income users (affordable service) and financial situation of incumbents;
- Transit is a private activity and must remain private; and
- Municipality role: planning and management of transit service (not operation).

These guidelines allowed the technical staff to define scope boundaries from the start of the project, however, they also set a pre-definition of technology (i.e., BRT) by imposing consideration of the incumbents' participation and the requirement of a system with low-cost for users.

#### **Transfer of Demand Risk to the Private Sector: Aerovia**

The municipality steered the Aerovia project towards a Public Private Partnership (PPP), including partial public participation in the initial investment complemented by the private sector's initial investment and operation for thirty years (the first of its kind in Ecuador) (Consultores A&V,

2015). Interviews indicated that the decision-makers were interested in transferring demand risk to the private sector, as well as detailed design, operation and maintenance, in hopes of aligning those aspects with efficiency and quality of service. This risk transfer also implied that having sufficient demand was crucial for the procurement model's success, therefore placing critical importance on the alignment.

Accordingly, the FS presented a thorough analysis of over thirty alternative alignments in search for the highest demand line. The analysis concludes that the best alignment connects Guayaquil with its neighbor, Duran, across the Guayas river. In this case, the policy of private participation that transfers demand risk to the private sector promoted an exhaustive analysis of alignment alternatives with the incentive of high demand (i.e., higher returns).

### **MCDA and “Do Nothing” Alternative: Tranvia and Aerovia**

Tranvia and Aerovia used MCDA to evaluate alternative technologies and alignments. This tool allowed a methodical approach, with results that are easy to understand for non-technical stakeholders (Consultores A&V, 2015) (Artelia, 2011). Moreover, Tranvia is the only project that includes a “do-nothing” alternative. The other projects make references to a “do nothing” scenario, but do not develop this scenario with the level of detail included in the Tranvia project.

## **4.3 Discussion**

### **Uniqueness of Driving Factors for Each Project and Component**

The results show that each project and component have a unique combination of factors. This stems from the individual complexity and context in which the projects were planned. For instance, Ecovia was planned during a severe economic crisis, and this is reflected in the importance of the financial factor for size and technology, but not for alignment. These diverse combinations confirm that rapid transit systems are large and highly complex, whose nature and context create distinct configurations (Ardila, 2002).

However, the pattern of substitution between financial and demand factors shows that when access to finance is more complex, demand is less relevant. This pattern is then restructured when the political factor gains influence, to the point that it overshadows all the remaining factors for size and technology. Hence, it can be concluded that the rationality of the process diminishes as access to financing becomes more complicated. Moreover, the planning process has become

increasingly dominated by politics since 2002, specifically for technology, similar to what Meyer and Miller (Meyer & Miller, 2001) describe as a political bargaining approach to the decision-making process. Political bargaining leads to compromises on different project aspects as a result of sometimes conflicting individual interests, which would otherwise be at a stalemate. Comparable findings were derived in France where the influence of external factors (politics) on the allocation of transport infrastructure has increased (Cadot et al., 2006).

### **Evolution of Factors that Affect Technology Selection**

The evolution of the factors for technology selection shows two distinct periods: 1991 to 2002 (BRTs) and 2003 to 2015 (rail and gondolas). The first period shows little political influence, while the second period shows a substantial increase where demand was largely replaced by political directives. Although no quantitative interview results could be collected for the rail projects, it is reasonable to conclude a similar trend is occurring, since the FS (Empresa Metro de Quito, 2012) (Artelia, 2011), the contractual documents (Publicas & Madrid, 2011), and political campaign promises, all showed an ex-ante preference for rail in both cases.

The preference for rail and gondola stemming from new political visions raises the question of why BRTs are being sidelined from the evaluation of alternatives (even electrical: trolleys or electric buses), in spite of Ecuador's extensive experience in implementing and running BRT systems. A potential explanation lies in the decline of BRT quality, as they reach the end of their lifecycles, especially due to operational complexity (e.g., RoW B, where transit shares portions of the alignment with regular traffic) and high demand (Dario Hidalgo & Graftiaux, 2006). For instance, in Guayaquil, Metrovia is colloquially referred to as "Metro Sardina", which makes a simile to a sardine can due to the overcrowded conditions. It is understandably difficult to promote a system with such an image and potentially beneficial to endorse new concepts. The predominance of the political factor could be seen as detrimental to the planning process, but as shown in other studies (Dimitriou, 2014) (Ardila, 2008), embracing this factor is essential for project implementation.

### **Gap Between Theory and Practice: Rational Process and External Factors**

In theory, the rapid transit planning process should identify and perform a thorough evaluation of all feasible alternatives utilizing objective measures (e.g., MCDA). However, the results from the Ecuadorian processes deviate from these theoretical guides. First, the identification of alternatives is absent in many processes, especially for technology (i.e., ex-ante definition); second, for the identified alternatives there are varying levels of depth and scope in the analysis of feasible alternatives, which show signs of ex-ante preferences. The results show that only one project, Trolebus, presents a complete demand and economic life cycle cost analysis for more than one technology alternative, as typically included in a rational planning process (Garber & Hoel, 2009; Vuchic, 2005). The remaining projects performed general analyses to discard potential alternatives or were contractually directed to a specific technology. Moreover, only two projects evaluated a “do nothing” alternative.

These findings raise two questions: 1) What are the underlying reasons and implications of the ex-ante selection of rail and gondola technology? and 2) What is required for a more rational (i.e., systematic) analysis of alternatives in the real-world rapid transit planning process? From an institutional perspective, the definitions of depth and scope of alternative design and evaluation are quintessential, however no such guidance was identified for the planning processes under study. In contrast, North America has developed guidelines and normative tools to promote the screening of alternatives (Regulations Electronic Code of Federal, 2019) and evaluation methodologies (e.g., business cases) (Metrolinx, 2017). From an academic perspective, since 2005, there is a noticeable increase in literature focusing on MCDA techniques for transport project evaluation (Camargo Pérez, Carrillo, & Montoya-Torres, 2014), which highlights a requirement for process improvement. Nonetheless, in Ecuador, no legislation, guidelines or academic research has been conducted in this subject area.

### **Results and Planning Relevance**

The above sections show policy implications in four areas: transparency, inclusion of external factors, normative developments and the transfer of demand risk.

First, transparency has been the exception rather than the rule and the political bargaining approach (Meyer & Miller, 2001) has grown. Hence, the planning processes should aim at providing as much information as possible on all feasible alternatives.

Second, the results show that the incorporation of positive elements from the external factors, specifically political support, and identification of the implications for project implementation and operation is crucial. Future planning process would benefit from embracing this approach, rather than a purely technical one.

Third, the absence of guidelines encouraged a variety of methods to support technology selection (in some cases ex-ante), and low accountability for differences between estimations and actual results. Moreover, the variance in approaches prevents a systematic review of the results with respect to specific techniques. Thus, the development and continuous refinement of guidelines to frame technology selection procedures are relevant for future improvements.

Fourth, the extensive analysis of alignment alternatives for Aerovia shows that transferring demand risk to the private sector promotes a thorough analysis of alternatives. This presents an opportunity to develop a framework and normative tools that promote rational alternative evaluation, based on the interest of private investors whose return depends on the balance between accurate demand estimation and project characteristics (infrastructure supply).

#### **4.4 Limitations**

The limitations of this research should be recognized and improvements for future exploration considered. The research includes projects dating as far back as 1991, which could have an effect on the recall ability of the respondents; however, none of the interviewees raised a concern in this regard. The process of evaluating the factors relies on individual judgements, which can include a degree of bias. Considering this, four measures were taken: 1) Selecting a method (AHP) that permitted comparison of the intensity of two factors with respect to each other; 2) Using the consistency index to exclude incongruent results; 3) Contrasting the quantitative results against project documentation and between project elements; and 4) Analyzing the results as orders of magnitude and direction.

Nonetheless, the quantitative results could be further refined by using a Delphi technique with a group of technical staff for each project. A systematic effort to continue data collection as planning processes are completed will be of great value. There is a degree of overlap between the external factors: political, financial and social. For instance, decision-makers tend to consider both social and financial factors in their analyses. This could lead to the political factor overlapping with the social and financial factors, and consequently overestimation of its relative importance.

Thus, contextualization and background knowledge are paramount to developing accurate understandings. In spite of several efforts, quantitative information for Quito's rail project could not be retrieved.

#### **4.5 Conclusions for the Design Process**

Analyzing the planning processes of past rapid transit projects and their factors is quintessential for understanding how the current systems were realized and provides much needed evidence for future process improvement. This part of the research focused on the evaluation of the relative significance of the factors driving rapid transit planning processes in Ecuador, in order to understand the gaps between theory and practice. This research was the first comprehensive analysis of all planned rapid transit projects in Ecuador, and was based on a mixed-method comparing nine planning processes through quantitative and qualitative analyses. The quantitative approach is based on AHP and utilized three project components (alignment, size, and technology), for which five factors were assessed (demand, local conditions, financial, social and political). Results were contextualized and validated for each project with documentation from their planning processes.

The comparative analysis of projects shows five key results: 1) Each project was unique and external factors introduced a varying degree of complexity into each planning process; 2) The systems' alignments and sizes were mostly driven by demand and local conditions (rational process); 3) The main factor driving technology selection has evolved over time from system demand to political factors (political bargaining approach); 4) Negative economic conditions had a large influence on the factors of all project components; and 5) There is a lack of rational alternative evaluation and an absence of corresponding tools/guidelines in Ecuador.

Nonetheless, several processes included practices that contributed to a more rational planning process: lifecycle cost analysis for the various technology alternatives (Trolebus), explicit decision-maker guidelines (Metrovia), transferring the demand risk to the private sector (Aerovia), and the use of MCDA (Tranvia and Aerovia). This shows that processes with rational alternative evaluations can be conducted, and the challenge is to create the conditions (incentives and normative) to promote them, especially to accommodate the political factor.

In Chapter 5, the implementation process is analyzed, in order to complete the study of the sequence of planning and implementation of rapid transit projects. The analysis is developed



through the lens of the barriers that hindered the implementation of the planned projects, and the elements that allowed for overcoming them, with special attention to the cases that never reached the implementation stage.

## Chapter 5

### **The Implementation: Factors that Determine the Execution of Rapid Transit Projects**

Nine rapid transit planning processes, encompassing eighteen projects, have been conducted in Ecuador. However, only nine projects reached implementation. This part of the research evaluates the critical barriers for project implementation along with corresponding mitigation measures. A mixed-method, based on an existing theoretical framework and Best-Worst Scaling (BWS), is proposed and applied. The analyses are grounded by in-depth interviews and surveys conducted with the technical teams of the planned projects.

The remainder of this Chapter is composed of five sections: 1) A description of the proposed methodology, which includes multiple case analysis thorough the review of project documentation/data, and BWS applied to survey results in order to evaluate the relative importance of the barriers; 2) A qualitative and quantitative analysis of the results, 3) A discussion of the barriers' relative importance and evolution, leading to the proposal of key mitigation measures for effective project implementation; 4) The limitations and 5) Conclusions that highlight the most relevant barriers for future rapid transit projects and the corresponding key mitigation measure to reach implementation.

#### **5.1 Methodology**

This part of the research proposes a new mixed-method approach that combines a multiple case comparative analysis and BWS. The process is threefold and starts by analyzing past projects and identifying their barriers. Subsequently, the process shifts towards the evaluation of the relative importance of barriers for current and future projects. Finally, strategies that promote effective project implementation (i.e., key mitigation measures) are identified, by using evidence from past projects and connecting it to current critical barriers in specific settings. This approach was applied to all the rapid transit projects in Ecuador, only half of which were implemented. Ecuador makes for an ideal study focus because its rapid transit projects are comparable.

### **5.1.1 Barrier Identification**

First, the planning and implementation processes were reviewed, to identify, characterize and contextualize the barriers. An existing theoretical framework (Mallqui & Pojani, 2017; Nguyen et al., 2019) was adapted to systematically classify the barriers in five categories for a structured analysis: institutional, technical, political, financial and social (Table 5-1). This theoretical framework is based on the findings of BRTs in Latin America and Asia (Dario Hidalgo & Graftieaux, 2008; Lindau et al., 2014) and consists of a structure of related barrier groups, for performing analyses from different perspectives (e.g., political, social, institutional, financial, technical). The proposed adjustments to the method build upon previous findings and refine the approach to fit the scope and perspective of the analysis. For this, it considers the specificities found in the projects under study and groups the barriers into five categories instead of seven. Table 5-1 presents the identified barriers with definitions and classified by category.

**Table 5-1 Barriers for rapid transit project implementation**

<b>Category</b>	<b>Barriers</b>	<b>Definition</b>
<b>Institutional</b>	1. Complex institutional processes and coordination	Institutional processes and coordination generate project abnormal delays or changes.
	2. Inadequate legislation/framework	Legislation does not support the development of the project (e.g., lack of competencies).
	3. Complex and lengthy expropriation and environmental processes	Resources required surpassed normal expectation (time, staff, funding) and result in large delays or archive.
<b>Technical</b>	4. Limited technical capabilities	Insufficient technical staff, experience or equipment to develop the project.
	5. Underestimation of implementation complexities (optimism bias)	Underestimation of the requirements to reach project implementation (e.g., time, finance, opposition).
	6. Inadequate management of competing modes	Competing modes could not be satisfactorily managed (e.g., prevent direct competition).
	7. Lack of community participation	Community input was not considered or did not play a relevant role in the project.
	8. Inadequate or insufficient project promotion	Project was not promoted in the community or promotion did not reach large audiences.
<b>Political</b>	9. Lack of political leadership, commitment or continuity	Political leader (Mayor) did not oversee or promote the project; changes in leadership (new cycle)
	10. Political frictions	Resistance or opposition from different government levels (e.g., lack of national government support)
	11. Lack of stakeholder alignment	Stakeholders had conflicting interest that were not addressed in the project.
	12. Rushed planning processes	Technical processes' times were reduced from standard timing ranges
<b>Social</b>	13. Opposition of incumbent operators and other affected parties	Concise actions from incumbents to prevent project implementation.
	14. Bias towards road capacity improvements	Concise actions to demote the project in favor of road expansion.
<b>Financial</b>	15. Inadequate funding	Lack of funding sources or required coordination.

Sources: (Dario Hidalgo & Graftieux, 2008) (Lindau et al., 2014) (Wu & Pojani, 2016) (Nguyen et al., 2019) (Ardila, 2002)

### 5.1.2 Evaluation of the Relative Importance of the Barriers

Second, the relative importance of the identified barriers was evaluated using BWS. This method is part of discrete choice analysis and is based on the seminal work of Louviere (1988). It is also a part of the MCDA ranking approach family, along with methods such as Preference ranking organization method for enrichment evaluation (PROMETHEE) and ‘Elimination Et Choix Traduisant la Realité’ (ELECTRE). BWS was selected for three main reasons: first, it provides a ranking of the elements in study; second, it is easy to comprehend for respondents and requires relatively short response times (i.e., more accurate responses and higher response rate); third, there are online software platforms available to administer the survey. The latter is of particular relevance, since the restrictions caused by the COVID-19 pandemic required such platforms.

The technique uses surveys where respondents select the most and least preferred (i.e., best and worst) attributes from a given set (Table 5-2). Unlike a Likert scale, where respondents may declare all attributes/barriers important (or not), BWS forces the respondent to make a choice of what is best and worst in a given set of attributes. By giving the respondent multiple questions (i.e., sets of attributes), BWS permits the analysis of the utilities of attributes on a relative scale. The survey design, data collection and processing were performed with Sawtooth Software (Johnson, 1983). The survey instrument is available in Appendix B.

**Table 5-2 Sample BWS survey question set**

From the list below, please select the MOST and LEAST relevant barriers for rapid transit project implementation		
Most relevant		Least relevant
	Inadequate management of competing modes	
✓	Lack of political leadership, commitment or continuity	
	Complex institutional processes and coordination	
	Limited technical capabilities	✓
	Inadequate funding	

In order to have a complete ranking, the respondents are presented with several sets containing a limited number of attributes (reducing respondent’s cognitive burden). Balanced Incomplete Blocks (BIBs) were used for the sets’ design. With this design, the set of attributes are of equal size, each attribute appears an equal number of times (frequency balance) and each attribute is paired with another attribute an equal number of times (orthogonality) (J. Louviere, Lings, Islam, Gudergan, & Flynn, 2013). The combinations of attributes allow for the inference of the relative

order of preference of all items (connectivity); and the appearance of each item and position are randomized to prevent bias (positional balance). Consistent with best practices, each attribute appeared at least four times, with a maximum of 5 attributes per set (Orme, 2005).

The simplest approach for analyzing the resulting survey data is to obtain choice proportions for each attribute: the count of “worst” is subtracted from the count of “best” (BW scores). For this, Louviere et al (2013) suggest to use the BW scores for each respondent and perform a basic statistical analysis of the resulting distribution (i.e., mean, median, standard error). The approach used in this research corresponds to the method applied by Sawtooth Software (Johnson, 1983). This method assumes that there is a utility associated with each attribute that can explain the choices made by the respondents. This utility function takes the form of an alternative specific constant ( $\beta_i$ ) for each attribute  $i$  (Equation 5-1), where one constant for attribute  $k$  is normalized to zero (i.e.,  $\beta_k=0$ ) to permit estimation of the remaining alternative specific constants.

$$V_1 = \beta_1 \tag{5-1}$$

$$V_2 = \beta_2$$

$$V_k = 0$$

...

$$V_n = \beta_n$$

where  $V_i$  is the utility of choosing attribute  $i$ , and  $\beta_i$  is the alternative specific constant corresponding to attribute  $i$ .

The method includes four major steps: the first step is the estimation of the coefficients ( $\beta_i$ ) for each one of the attributes. For this purpose a hierarchical Bayes (HB) procedure is used on the observed choice data (J. J. Louviere & Woodworth, 1983; Train, 2009, Chapter 12.6). The resulting parameters ( $\beta_i$ ) are interpreted as “weights” of each attribute.

In the second step, the resulting weights are zero-centered. Zero-centering has no effect on the choice probabilities since utility is relative in discrete choice models. For this purpose, the average of the weights is subtracted from each weight (Equation 5-2).

$$U_i = \beta_i - \frac{\sum_{j=1}^n \beta_j}{n} \tag{5-2}$$

where,  $U_i$  is the zero-centered weight,  $\beta_i$  is coefficient for attribute  $i$ , and  $n$  is the number of attributes.

In the third step, the probability of choosing each attribute in a given choice situation are calculated. This is performed using a multinomial logit model (Equation 5-3).

$$P_i = e^{U_i} / (e^{U_i} + n - 1) \quad (5-3)$$

where  $P_i$  is the probability of selecting attribute  $i$ ;  $U_i$  is the zero-centered weight of attribute  $i$  and  $n$  is the number of attributes in a set containing  $i$  (such as Table 5-2). Note that  $n - 1$  appears in the denominator of equation 5-3, since the expected value of each other attribute in the set is  $e^0 = 1$  (because the weights are zero-centered).

In the fourth step, since the resulting probabilities ( $P_i$ ) correspond to choices made by the respondents between a limited set of attributes in each question (i.e., five attributes per question in this study), the probabilities from equation 5-3 are rescaled to sum to 100 (Equation 5-4). The rescaled probabilities follow ratio scaling, and hence are interpreted as the relative importance of the attribute (i.e., 6 is twice as important as 3).

$$Pr_i = \left( P_i / \sum_{i=1}^n P_i \right) \times 100 \quad (5-4)$$

where  $Pr_i$  is the rescaled probability of selecting attribute  $i$ ;  $P_i$  is the probability of selecting attribute  $i$  and  $n$  is the total number of attributes in the study.

### 5.1.3 Identification of Key Mitigation Measures

The third and final step of the research methodology identifies key mitigation measures to improve project implementation based on the empirical measures used to overcome critical barriers in past projects. Special attention is given to mechanisms that provide feedback to the rational planning process. The results were compared to the findings from other developing cities in order to confirm their transferability or their country specific nature.

This research methodology was enabled by significant data collection including project documentation (i.e., feasibility studies, technical notes, procurement and contractual documents), interviews and surveys. As indicated in Chapter 4, eight in-depth interviews were conducted with senior members of the technical teams (i.e., project managers, agency directors and senior engineers/planners) between July and August 2019 in three cities: Quito, Guayaquil. The interviews aimed at reconstructing and contextualizing the planning and implementation process of past projects. In combination with literature review, these interviews provided the basis to

identify the barriers and design the survey instrument for this research. Table 5-1 presents the identified barriers for rapid transit implementation in Ecuador, classified into five categories.

A subsequent survey asked senior technical staff with prior experience in rapid transit implementation to evaluate the relative importance of the barriers for future projects. It contained three sections. First, the BWS section asked respondents to compare fifteen attributes using nine questions/sets of 5 attributes each. Second, respondents were asked to identify the project(s) in which they had or have direct experience. Third, the respondent was asked to provide the most relevant barrier (contextualization) and the measures that were used to overcome it. The survey was completed by the senior technical staff (agency directors, project managers and senior engineers/planners) with in-depth knowledge of the projects and was conducted in October 2020. Thirty-four respondents were identified and contacted individually with a personalized email. An 85% response rate was obtained (n=29), which provides observations that encompass respondents with experience from all previous projects (i.e., at least three observations connected to experience from each previous planning process).

## 5.2 Quantitative and Qualitive Analyses

Nine rapid transit planning processes (19 trunk lines) were studied in Ecuador and only half (i.e., 9) of the planned trunk lines reached implementation (Table 5-3). Metrovia phase 2 (4 trunk lines), Cuenca’s BRT, Quito Cables (4 trunk lines) and Trole Norte remain archived, in spite of having conducted detailed engineering studies, and in the case of Quito Cables Line 1, the expropriation procedures.

**Table 5-3 Project information**

	<b>Project Name</b>	<b>Number of trunk lines</b>	<b>City</b>	<b>Planning Year</b>	<b>Implemented</b>	<b>Planning process</b>
1	Trolebus	1	Quito	1991	Yes	Individual
2	Ecovia	1	Quito	1995	Yes	Individual
3	Central Norte	1	Quito	2000	Yes	Individual
4	Metrovia phase 1	3	Guayaquil	2002	Yes	Joint
	Metrovia phase 2	4			No	
5	Subway Quito	1	Quito	2010	Yes	Individual
6	LRT Cuenca*	1	Cuenca	2009	Yes	Individual
7	Aerovia	1	Guayaquil	2015	Yes	Individual



8	Quito Cables	4	Quito	2015	No	Joint
9	Trole Norte	1	Quito	2015	No	Individual

\* A previous BRT project using a similar alignment did not reach implementation.

**5.2.1 Qualitative Barrier Analysis**

The qualitative analysis is based on the project’s documentation and in-depth interviews, which reconstructed the decision-making processes. This analysis identifies the barriers (individual and combinations) that led to archival and the underlying rationale behind these decisions. For each category, the analysis presents selected projects to illustrate critical barriers as well as successful approaches that mitigated the barriers.

**Institutional**

The three institutional barriers (Table 5-1) were relevant during the projects’ advances, but in no case forced the archive of a project. This is confirmed when the non-implemented systems were developed under the same institutional setting as the ones that reached implementation for analogous projects (e.g., Guayaquil Metrovia, Cuenca BRT). To overcome institutional barriers, the municipalities found ways to build minimum levels of institutional capacity and coordination, with the creation of technical units and the support of international consultants and agencies (i.e., United Nations Development Program (UNDP), IADB, World Bank (WB), Latin America Development Bank (CAF)). Quito led the way with the first transport planning technical unit in the country and the passing of legislation that provided competencies to municipalities, which were previously held at the national level by the police department. With this normative advance, the rest of the cities developed further legal capacities that permitted the completion of projects.

Furthermore, the ability to overcome the institutional challenges remained invariant for different technology requirements (BRTs’ right of way protection, rail and gondola specific requirements: privacy, fire hazard protection, sound and vibration maximum acceptable levels). Nevertheless, the interviews showed that aligning the visions of different stakeholders within the municipal institutional settings was a complex and time-consuming task that requires project managers and political stakeholders’ continuous involvement.

## **Technical**

The technical category includes five barriers with distinct effects. First, the technical capabilities in the municipalities were not an issue that ultimately determined the implementation outcome. The technical limitations were overcome with assistance from international agencies (e.g., IADB, WB, UNDP, CAF) and consultants. Second, the over-optimistic approach (i.e., underestimation of complexities) identified in several projects, especially rail projects (Quito, Cuenca), did not hinder their ability to reach implementation; rather it promoted advancement to implementation, although its effects remain unclear, as both projects showed evidence of being overbudget and overtime. This is similar to what Flyvbjerg (2009) called “survival of the unfittest”, where projects that present optimistic figures are often prioritized and promoted (e.g., demand overestimation in CN (Chapter 6)). Third, the effects resulting from management of competing modes vary according to technologies. BRT is highly sensitive in this area, since it competes directly with the service provided by incumbents. This barrier was relevant, but did not prevent implementation in any of the cases. For instance, the implementation of Trolebus led to city wide incumbent protest but did not derail the project, as it had ample community and political support. Moreover, for the subsequent projects, the incumbents’ opposition was marginal in comparison. Fourth, none of the projects showed signs of adequate community participation. The feasibility studies and other documentation included little to no community input, and focused almost exclusively on the technical tasks. Fifth, project promotion had not been given the same attention as other technical processes and projects present little to no evidence of promotion in the planning stage.

## **Social**

Social barriers were present in the projects, but were not a standalone determinant for implementation. Trolebus and Ecovia suffered severe incumbent opposition (i.e., protests), but were positively perceived by the majority of the community since the incumbent’s service was of low quality and resulted in uncomfortable trips for the majority of citizens. In the same line, a bias towards road capacity has been present, especially when the new systems reduce the number of lanes for regular traffic. This bias is often led by private vehicle owners and is not representative of the majority (as surveys of Trolebus showed). Nevertheless, community support is often invisible and can only be detected through large surveys. These individuals can be considered a

“silent majority” since the group has no voice in the media (Agarwal, Zimmerman, & Kumar, 2018).

Quito Cables’ archive is the result of a combination of barriers. The rushed planning processed defined several expropriations for a gondola stations, but lacked community input. Although all administrative/legal processes were completed, the social protest stopped construction several times and the project was canceled when a new mayor took office. The station location choices conflicted with community interests. This could have been prevented if the station was located over the traffic lanes (similar to Guayaquil’s Aerovia), suggesting there was a lack of community input during the planning process. In this case, political continuity, rushed processes, and social opposition combined to bring the project to a halt. This is the only case where a combination of barriers led to a project’s archive. Moreover, a technical barrier (lack of community participation) manifested through social protest.

## **Financial**

Funding barriers were relevant; however, they did not prevent implementation. Quito financed over 2 billion USD (2% of the country’s GDP) for its subway and Cuenca financed close to 300 million USD for an LRT. Moreover, in the midst of an economic crisis, Quito was able to creatively finance Ecovia with a domestic loan. Hence, funding has been attainable and did not directly prevent project implementation. Municipalities accessed financial resources through national and international institutions. The latter required coordination with the national government as sovereign collaterals are standard requirements for developing cities. For Quito’s subway, the massive financial effort required the coordination of three financiers (IADB, WB, CAF), as well as local and national governments. The coordination between the two government levels is crucial.

Aerovia (Guayaquil 2015) recognized this need and took a different approach by developing a Design Build Finance Operate Maintain (DBFOM) procurement approach to secure international financing and implement a more efficient management model. This procurement approach fast tracked the issuance of sovereign collaterals by developing a complete financial scheme and eliminating the national government’s direct intervention. In addition, this procurement approach promoted a more systematic evaluation of alternatives (see Chapter 6). In contrast, for Metrovia phase 2 (Guayaquil 2002), political differences undermined the possibility of securing adequate funding, but more importantly the support of the national government to

incumbent operators ultimately prevented the project completion. In this case, political factors were the main barrier to project implementation, but they ultimately manifested through funding and social factors.

## **Political**

The four planning processes (i.e., nine trunk lines) that did not reach implementation, showed that the political barriers were critical (political leadership/commitment/continuity). Metrovia phase 2 and Cuenca's BRT were directly affected by political agendas. Metrovia suffered from a conflict between local and national governments that resulted in its archive (national government support to incumbents' opposition). Cuenca's BRT (ready for implementation) was discarded when a new municipal administration was elected and decided to fulfil the campaign promise of an LRT (similar case to Quito's Subway). In the case of Quito cables, the combination of barriers described earlier, led to a new political authority to cancel the project. Finally, Trole Norte has been on hold for several years in spite of having completed detailed engineering design (i.e., with a lack of political will to start).

The political barriers stand out as the critical elements that prevent project implementation. Within this category, the political continuity/will rises as the most frequent. The interviews and documents revealed that for Trolebus, Ecovia, Quito Subway and Cuenca's LRT, the newly appointed mayors were keen to evaluate alternatives in order to terminate the projects. However, in all cases, infrastructure construction was underway and prevented the projects' archive.

Political frictions depict a heavy dependence of the municipalities vis-à-vis the national government in two areas: funding and support (to opposing groups). These dependencies are new elements to the earlier finding that national policies need to support transit (Lindau et al., 2014). Moreover, it shows that DBFOM was an effective tool to overcome complex coordination processes with the national authorities. The definition, at the planning stage, of a scheme that gives more autonomy to the municipalities was crucial in light of political frictions between government levels (Aerovia). Table 5-4 shows the barriers that had a direct and critical effect in the implementation of the projects.

**Table 5-4 Critical barriers for project implementation**

	Barriers/Projects	Implemented projects						Non-implemented projects				
		Trolebus	Ecovia	Central Norte	Metrovia phase 1	LRT Cuenca	Subway Quito	Aerovia	Metrovia phase 2	BRT Cuenca	Quito Cables	Trole Norte
Institutional	Complex institutional processes and coordination											
	Inadequate legislation/framework	✓										
	Complex and lengthy expropriation and environmental processes											
Technical	Limited technical capabilities											
	Underestimation of implementation complexities (optimism bias)					✓	✓				✓	
	Inadequate management of competing modes											
	Lack of community participation										✓	
	Inadequate or insufficient project promotion											
Political	Lack of political leadership, commitment or continuity	✓	✓			✓	✓		✓	✓	✓	✓
	Political frictions							✓	✓	✓		
	Lack of stakeholder alignment										✓	✓
	Rushed planning processes				✓						✓	
Social	Opposition of incumbent operators and other affected parties	✓			✓							
	Bias towards road capacity improvements											
Financial	Inadequate funding		✓									

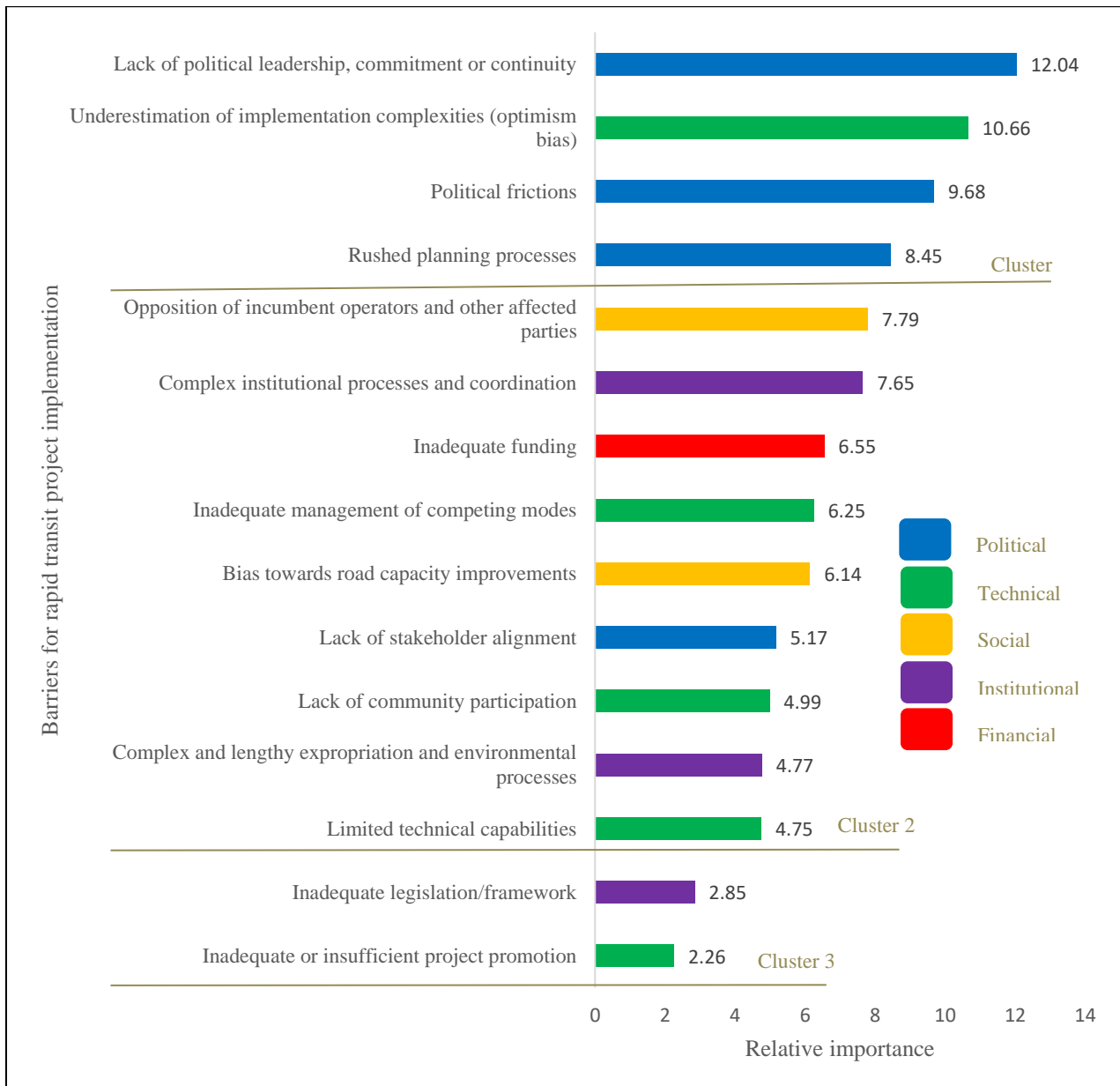
## 5.2.2 Quantitative Barrier Analysis

The quantitative analysis focuses on evaluating the relative importance of the barriers for future rapid transit projects through BWS. The interpretation of these results considers orders of magnitude and direction rather than precise values due to the nature of the data. Figure 5-1 shows the ranking of barriers (i.e., relative importance) derived from their rescaled logit probabilities. In Figure 5-1, the numerical values associated with each barrier correspond to the probability that a respondent identifies that specific barrier as the most relevant for project implementation (e.g., there is a 12.04% probability that a respondent identifies lack of political leadership, commitment, or continuity, as the most relevant barrier)

Barriers were classified into three main clusters based on their relative importance. These clusters were defined using *k*-means clustering analysis (i.e., groups the scores to the closest cluster center). Table 5-5 shows the cluster centers and the number of barriers in each cluster.

The top cluster includes four critical barriers and is dominated by three political barriers. Lack of political leadership, commitment or continuity is the most relevant barrier, followed by underestimation of implementation complexities, political frictions and rushed planning processes.

These results align with the qualitative analysis, where political barriers were critical in preventing project implementation. The second cluster is composed of nine barriers (see Figure 5-1) and includes all barrier categories (i.e., political social, institutional, financial and technical). The importance of these barriers varies approximately between 1/2 and 1/3 with respect to the top barrier (i.e., political leadership, commitment or continuity). The last cluster includes only two barriers, inadequate legislation/framework and inadequate project promotion, which correspond to the institutional and technical categories, respectively.



**Figure 5-1 Relative importance of implementation barriers for rapid transit in Ecuador (rescaled logit probabilities)**

**Table 5-5 Cluster classification results**

<b>Cluster center</b>	<b>Number of barriers in cluster</b>
10.21	4
6.01	9
2.55	2

### **5.3 Discussion**

This section uses the quantitative and qualitative results to understand the rationale behind the different barriers and their effects. By identifying success factors that have proven effective for overcoming these barriers in the past, a set of contextualized key mitigation strategies for future projects is developed.

#### **5.3.1 Institutional and Technical**

Institutional and technical barriers were more prevalent during the 1990's and 2000's. In this period, municipalities started developing the legislation, frameworks and teams required for rapid transit planning and implementation. Nevertheless, the early projects (six implemented BRT trunk lines) were developed by internal teams, which is a testament to the required institutional and technical resources. The support of international agencies (e.g., UNDP) and financiers (i.e., WB, IADB, CAF) played a key role in planning and implementation, with the inclusion of experienced consultants familiar with the region (e.g., Brazil, Argentina) to address specific topics. More recent projects (rail and gondola) have been developed externally (i.e., international consulting companies), an approach that has proven equally successful. The assistance of experienced advisors was a key factor to achieve implementation throughout the past three decades. However, when comparing the procurement approaches of Quito's Subway and Guayaquil's Aerovia (traditional vs. DBFOM, respectively), the former required additional support, as all the responsibility fell on the municipality. Whereas, the DBFOM approach liberated the municipality from several processes and permitted its focus on issues requiring public intervention (e.g., expropriation, permits, media). Hence, two key findings arise:



- 1) Due to the complexity and scope of the projects, and regardless of the selected technology, expert advisory services played crucial roles. Acquiring specialized support was relevant for the projects' implementation and future projects should continue to seek these types of support.
- 2) A traditional procurement approach implied that the municipality had to dedicate more resources for planning and implementation (e.g., creation of independent units for this purpose: additional staff, infrastructure, and financial resources). A DBFOM approach develops and manages the project with a more streamlined institutional structure and focuses the municipality on tasks that require public intervention. Moreover, the analysis shows that complex institutional processes and coordination are detrimental to project implementation. Hence, projects will benefit from evaluating a DBFOM procurement as an alternative that promotes project implementation. If a traditional procurement is selected, the implied additional resources and processes should be considered.

### **5.3.2 Social**

Social barriers materialized in the form of community opposition (i.e., incumbents, affected groups). This opposition derived from two main sources: the bias towards road improvements and the lack of community participation during the planning stages. The question is how the projects gained community support. The projects that received community support relied on the following key strategies:

- 3) Public opinion was monitored through the use of surveys with regards to the effects of the project in the community (Trolebus, Metrovia). This outreach developed an understanding of the community's concerns and their level of support, and could be leveraged to promote project implementation.
- 4) The project's features were adapted to mitigate drawbacks, when possible, is essential (i.e., implementation driven approach) (Metrovia, Aerovia). For this, promoting and embracing community input during the planning process is key. The lack of community input was found to affect the possibility of project implementation and became a critical issue when political

continuity/will and rushed processes were present (Quito Cables). Thus, adapting a project's features also mitigates the negative effects of political continuity/will by easing the transition between political cycles.

These strategies highlight the importance of interactions between technical staff and social stakeholders during the planning process. For instance, generating ample community support neutralized incumbent's opposition to new corridors (BRTs). The technical procedures should not be dissociated from the social perspective, since they are relevant for project implementation. A purely technical approach is more likely to result in a project's archival (Quito Cables). Mechanisms to involve the community in a system's planning and implementation can be found in literature (Muñoz & Hidalgo, 2013) and should aim at advancing the social stakeholder buy-in, especially from existing private operators and the affected parties. In the age of social media and considering the silent majority of rapid transit beneficiaries, this is a topic that warrants further research (Agarwal et al., 2018).

### **5.3.3 Financial and Political**

The financial and political barriers are closely related. Securing adequate funding has been a highly political process that requires coordination between local and national governments and international agencies. Guayaquil showed that changing the approach, from a national government dependent process (traditional procurement) to a more independent framework (DBFOM), was successful amidst these frictions. However, this approach also required a concessionaire with access to financial resources. Thus, new schemes for BRT system implementation, with higher private participation, should be evaluated.

- 5) A procurement approach that increases the autonomy of the municipalities was positive for project implementation. Non-traditional procurement (e.g., DBFOM) should be evaluated thoroughly during the early planning stages, especially in the presence of antagonistic governments.

On the political arena, the level of project advancement played a key role in surviving changing political cycles. Projects that started physical implementation (construction) amid changes in

political cycles were implemented (Trolebus, Ecovia). Completing detailed design (Metrovia phase 2, Quito Cables) and initiating contractual processes did not ensure project implementation (Quito Cables, Subway).

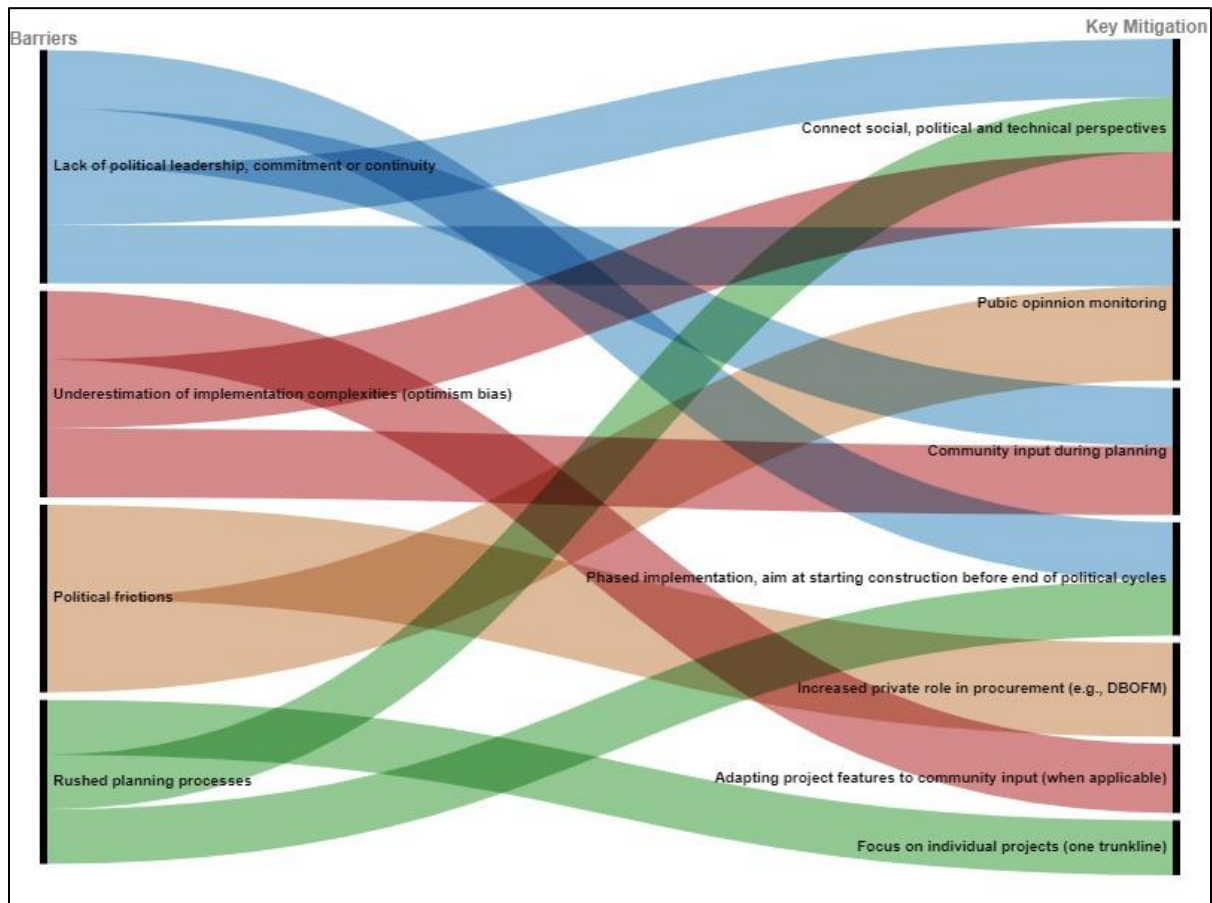
- 6) Aiming at starting construction before the end of political cycles and considering a phased approach to implementation is a solid strategy to safeguard project implementation (Trolebus, Ecovia, Aerovia).

The planning processes that included more than one project (Metrovia phase 1, Quito Cables) include two different approaches. One process set a target to implement a project every two years by focusing resources on only one line at a time. The other process rushed projects for several lines and was unsuccessful in project implementation.

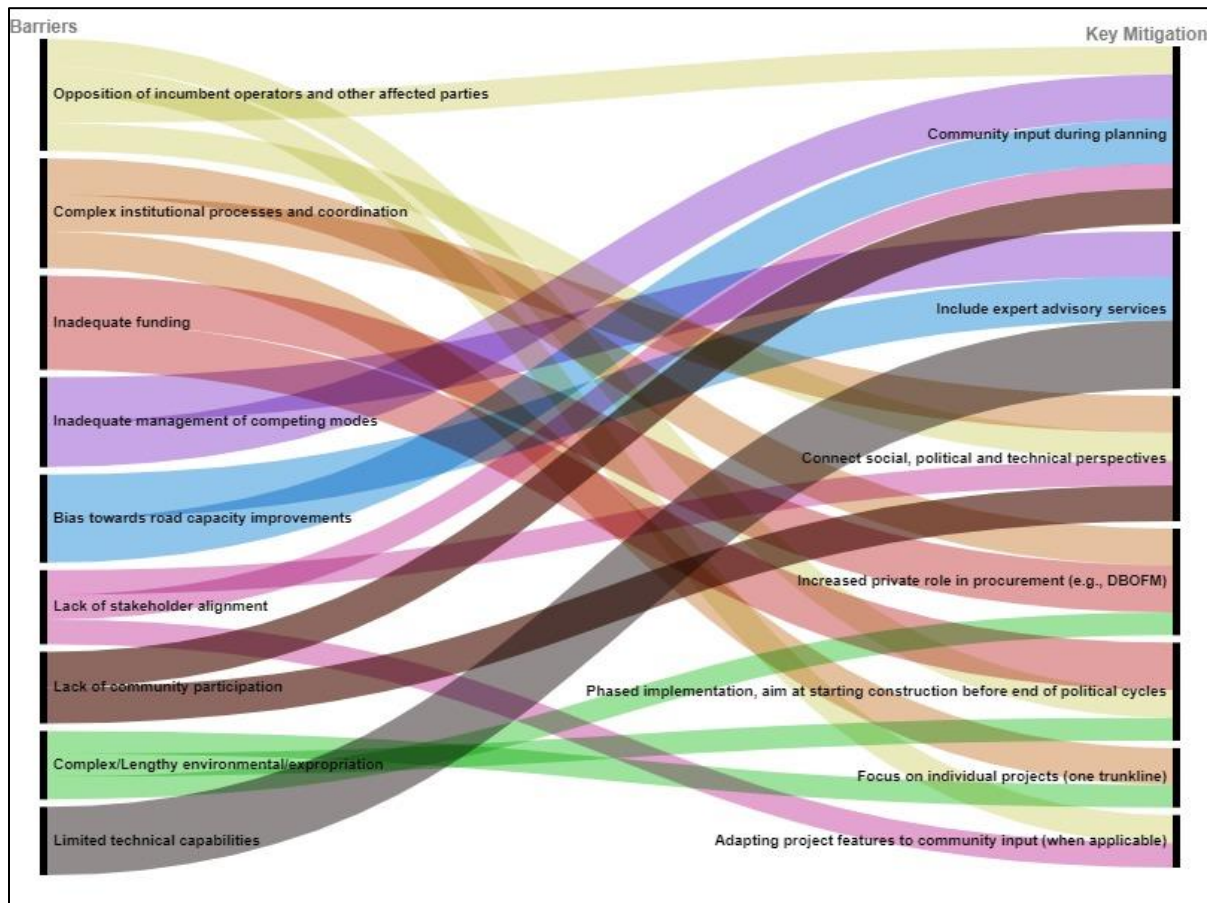
- 7) Focusing on the implementation of individual trunk lines and avoiding attempting more ambitious endeavors (Quito Cables) promoted project implementation.

From the above key points, it is possible to derive seven key mitigation measures to promote project implementation: 1) Connect the social, political and technical perspectives and include expert advisory services; 2) Increase the private role in the procurement strategy (e.g. DBFOM); 3) Generate public opinion monitoring; 4) Increase community input during planning; 5) Adapt projects features to community input (when applicable); 6) Aim at starting construction before the end of political cycles (phased implementation); and 7) Focus on the implementation of one trunk line at a time.

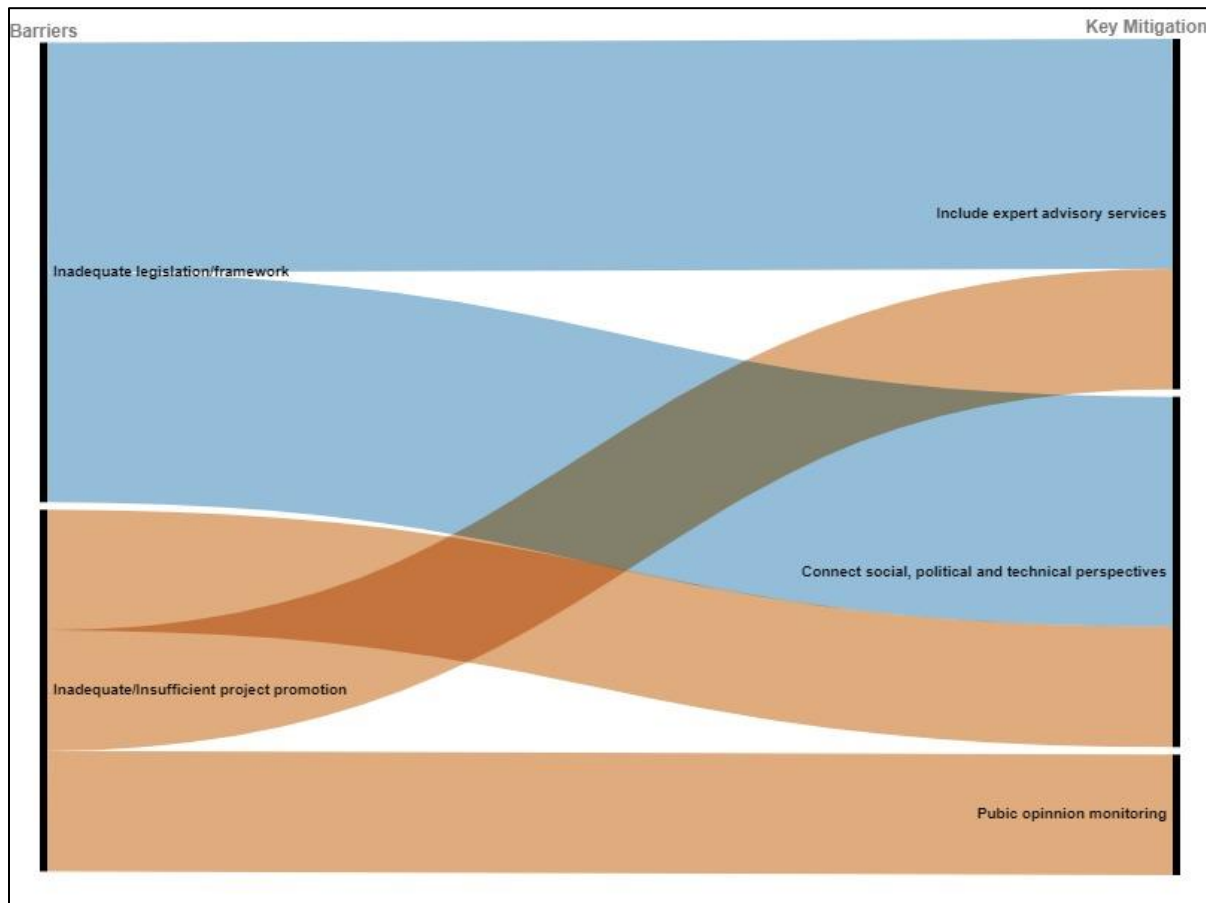
Figure 5-2 shows a graphical representation of the connection between the critical barriers (left side) connected to the key mitigation measures (right side) for cluster 1 (i.e., top tier). Figure 5-3 and Figure 5-4 depict similar connections for clusters 2 and 3, respectively. The width of the barriers corresponds to the importance identified in the quantitative results (Figure 5-1) and the width of the key mitigation measures corresponds to the number of times it was identified empirically as an effective measure that mitigated barriers in the past. All the connections from the preceding discussion were characterized.



**Figure 5-2 Barriers and key mitigation measures for cluster 1**



**Figure 5-3 Barriers and key mitigation measures for cluster 2**



**Figure 5-4 Barriers and key mitigation measures for cluster 3**

The preceding results and analyses lead to two fundamental questions: 1) Why do political leaders choose not to support implementation for some planned projects? and 2) Why do political leaders fail to implement some projects they have chosen to support? Implementation’s critical dependence on political factors can be traced back to several projects’ inception (i.e., political campaigns): Quito’s Metro, Cuenca LRT, Quito Cables, and Trole Norte. As such, the selectivity in support for project implementation seems to be routed in campaign promises of “new and better” systems that would attract voters. A second contributing factor is the opposition of affected parties, which discourages newly appointed mayors from supporting the implementation of projects planned under previous administrations (e.g., Quito Cables).

With respect to the second question, failures in political leadership reveal the complexity of undertaking rapid transit projects and were rooted in rushed planning timelines and underestimation of implementation complexities (Quito Cables). Moreover, these failures highlight the relevance of the technical team's capacity to interact with different stakeholders, and in particular political actors, balance their interest and maintain sound technical project features.

For the projects under study, the critical dependence of implementation on political support contributed to long-term planning being the exception rather than the rule. This fundamental disconnect between political cycles and long-term planning was highlighted in the responses to the last section of the survey, which contextualized the critical barriers and identified measures to overcome them. Three elements were identified. First, the disconnect between the technical and the political perspectives led to persistent recommendations of supervision from independent agencies that can oversee/approve the planning and implementation of rapid transit projects. This does not imply limiting the autonomy of municipalities, but rather reinforcing their long-term planning. Second, there is a need to promote long term planning processes independent of political cycles. As Cuenca's LRT and Quito's subway and cable projects showed, the electoral promises affected long term planning processes, especially project implementation and also ex-ante technology selection. Third, the increasing importance of transparency and community inputs for project implementation was highlighted. A lack of transparency and community input contributed to short term planning based on political cycles, rather than long-term community visions that were reflected in public documentation.

### **Transferability of Findings in Comparable Settings**

Literature has identified barriers and mitigation measures for rapid transit in other developing cities. Those findings present similarities to the results of this research in terms of the technical, social, financial and political categories. First, the technical barrier was not critical for project archive (Lima, Bogotá and Hanoi) (Ardila, 2002; Mallqui & Pojani, 2017; Nguyen et al., 2019). Second, the financial and social barriers have been more relevant than the technical barrier for a projects' implementation. Third, discontinuities in the political cycles contributed to project archive (Guadalajara, Lima, Bogota and Bangkok) (Ardila, 2002; Lindau et al., 2014; Wu &

Pojani, 2016). Moreover, the opposition based on political affiliation was particularly relevant; this is similar to the case of Metrovia phase 2 (Guayaquil). Fourth, the combined effect of different barriers resulted in severe project complications (e.g., Bangkok: political conflict, political discontinuity, inadequate management of competing modes) (Wu & Pojani, 2016).

However, the institutional factors showed a different pattern in Ecuador compared to previous research. For example, the institutional barrier was highly relevant for Lima, where several municipal jurisdictions had to coordinate efforts to implement rapid transit (Mallqui & Pojani, 2017). In Ecuador, the only project with this characteristic was Aerovia, however, no evidence of problematic coordination was found. The rest of the projects were located under a single jurisdiction, since single municipalities cover large urban areas in Ecuador.

The recommendations from other developing cities are similar to the ones identified for Ecuador, of which five stand out 1) Developing standalone projects (Nguyen et al., 2019); 2) Ensuring the project's continuity with legal mechanisms for changing political cycles (Mallqui & Pojani, 2017); 3) Promoting thorough analysis of alternatives (e.g., rail vs. BRT) (Nguyen et al., 2019); 4) Promoting systematic community participation (Lindau et al., 2014; Nguyen et al., 2019); and 5) Connecting the technical, political and social perspectives (Ardila, 2002).

In addition to these previously identified mitigation measures, the connection between the technical, political, and social perspectives, as well as the community input, are critical for the implementation of rapid transit. The former is critical to develop realizable projects (i.e., projects that reach implementation) (Ardila, 2002). The latter is fundamental to prevent the effects of political discontinuity (Lindau et al., 2014; Nguyen et al., 2019). Moreover, it was detected that in Ecuador, as well as the other comparable cities, community participation is limited to the inform stage, rather than the cycle of inform, consult, involve, collaborate and empower (Lindau et al., 2014). These missing pieces of the community engagement process are quintessential for transparency, stakeholder alignment, long-term planning and to prevent the negative effects of changing political cycles (Nguyen et al., 2019).

The transferability of these findings is adequate for aggregate analyses, but requires an in-depth study of the specific characteristics of the project and its environment. The relationships in terms of barriers and mitigation measures are subject to particularities, such as jurisdictional



features that generate different challenges. Hence, the identified barriers and mitigation measures should be interpreted considering their specific context and the pertinence for other settings evaluated in accordance with the specificities of that environment. It is expected that these findings will contribute to bridge the gap between theory and practice, in particular the connection between the political, technical and social perspectives and the community input during project planning.

#### **5.4 Limitations**

This research identified the barriers from the perspective of the senior technical teams (quantitative and qualitative) in order to develop a holistic perspective on project implementation. The study identified and contacted respondents from all planned projects (85% response rate, n=29). The number of observations in the analysis corresponds to all the identified and available respondents that fit the selection criteria (i.e., senior technical personal involved in the projects planning and implementation processes). In order to prevent bias, the following efforts were made: comparisons between the technical perspectives and project documentation were made to validate the survey results and identify inconsistencies; the quantitative results were compared to the qualitative (i.e., reconstruction of the processes) to confirm congruency; the results are approached as interpretative within the context of each project rather than systemic. This last point is also relevant, since there is a degree of overlap and interconnection between barriers, thus, the results should be interpreted within the context of each project.

Regarding BWS, the limitations of the method include the inherent assumption of a personal utility scale, common for discrete choice experiments, under which, respondents make their choices of ‘Best’ and ‘Worst’. However, in this case the respondents are selecting the ‘Best’ and ‘Worst’ choices based on empiric observation of the projects’ outcomes, which is closer to a revealed preference response, rather than a stated one. This method does not include a tool to evaluate the consistency of the choices made by the respondents. Finally, by utilizing a logit model approach, there are also implicit limitations of this method, including the assumption of Independence of Irrelevant Alternatives (IIA) (i.e., proportional substitution across alternatives)

stemming from assumed distribution of utility random error terms (independently and identically distributed (iid) Gumbel) (Train, 2009, Chapter 3).

## **5.5 Conclusions for the Implementation Process**

This chapter presents the first study of barriers and key mitigation measures for rapid transit implementation in Ecuador. Previous analyses, conducted in other developing cities, focused primarily on BRTs and relied on qualitative methods. This research addressed the gaps in the analyses of barriers by considering three different technologies (i.e., BRT, rail and gondola), including the planned but non-implemented projects. Moreover, a methodology to derive an objective ranking of barriers was developed to complement the previously employed qualitative methods.

Results indicate the top tier of critical barriers is composed of 1) Lack of political leadership, commitment or continuity; 2) Underestimation of implementation complexities; 3) Political frictions; and 4) Rushed planning processes. In addition, it was identified that critical barriers are not technology specific, but rather endemic to the planning process. Considering the above points and based on the empirical project data, seven key mitigation measures were identified: 1) Increase the private role in the procurement strategy (e.g. DBFOM); 2) Generate public opinion monitoring; 3) Connect the social, political and technical perspectives; 4) Increase community input during planning; 5) Adapt projects features to community input (when applicable); 6) Aim at starting construction before the end of political cycles (phased implementation); and 7) Focus on the implementation of one trunk line at a time. These mitigation measures were matched to specific barriers in order to characterize their viability. These connections suggest that a bundle of key mitigation measures may be needed to address a particular barrier.

The critical dependence of implementation on political support fostered short-term planning based on political cycles in detriment to long-term visions. The senior technical teams highlighted the relevance of external supervision to apply long-term planning independent of political cycles (not political input). For this, community input and transparency emerge as paramount elements. These findings align with previous results from developing cities, confirming

the transferability of results at an aggregate level, but also showed that the barriers and corresponding mitigation measures can be context specific and thus, should be evaluated accordingly.

The analysis of context specific measures is clearly illustrated by the differences in the implementation approaches taken by Quito and Guayaquil in their respective BRTs. The analogous projects (i.e., BRTs with similar features and socio-economic context) present a unique opportunity to evaluate the effects of one differentiation factor: the level of private participation. Chapter 6 presents a comparative analysis of these cases.

## Chapter 6

### **The Effects of Private Participation in Rapid Transit Projects**

Municipalities across Latin America have chosen different paths for implementation and operation of rapid transit systems, and in particular for BRT projects. In the first developments of BRT, Curitiba and Bogota choose private operations, while Quito took a public approach. Each system presents particular conditions for implementing the project and can have a wide range of private participation (Rall, Reed, & Farber, 2010). The PPP approach can be tempting for financially constricted Municipalities because of its potential to recruit private capital (Matti Siemiatycki, 2006), but the vision, the Project Delivery Method (PDM) and the operation have deeper implications in the overall performance of the projects and should be carefully evaluated.

One approach for the evaluation of the project's success is to consider the performance of infrastructure execution (i.e., implementation) and the operation. Research for North American projects, conducted by Touran, Gransberg, Molenaar, & Ghavamifar (2011) determines main advantages of PPPs such as cost savings, schedule reduction, risk allocation and fewer regulatory procedures. However, it is not clear if these findings are applicable to Latin America cities where the environment changes drastically. One crucial difference is that transit services depart from an existing and unintended PPP, where the fixed components are provided by the public authority (roads, terminals) and the rolling equipment and transit services are provided by a vast number of private operators (without subsidies). Hence, the base scenario for a transit project contains a different risk allocation scheme. In this context the risk allocation analysis is crucial to understand the implications of the project success. According to research conducted by Osei-Kyei & Chan (2015) the number of studies regarding PPP risk allocation for developing cities remains low. Nonetheless, they identify five key success factors common in the literature: risk allocation and sharing, strong private consortium, political support, public support and transparent procurement.

Regarding project delivery methods selection, extensive literature can be found (Touran et al., 2009), often comparing the impact of traditional procurement to PPP on public infrastructure (S. Carpintero & Petersen, 2015) and specifically for measuring project performance in the

transport sector (Roumboutsos, 2015) (Diana & Daraio, 2010). However, as the public infrastructure becomes a more specific subject, literature narrows down, to the point that little can be found regarding the impact of private participation in BRT systems in Latin America. Even in developed countries such as Canada, academic research is not abundant in this field (Matti Siemiatycki, 2006) and the benefits of more private participation are uncertain.

Hidalgo & Graftieaux, (2008) identify several common barriers for the operations of rapid transit systems in Latin America: problematic initial operations, high occupation, fare setting mechanisms and strong opposition from private operators. Nonetheless, each country and city have particular characteristics that influence the design, performance and final success of the systems. Furthermore, Hidalgo & Carrigan, (2010) indicate that performance measures for BRT in Latin America show a wide range of results and the implementation of the systems shows to be problematic in all the cases. The reasons for the dispersion of the results and the difficulties in implementation remain unclear. Willoughby (2013) finds evidence of positive results from PPP in urban transport in six developing countries, and notes that there is need for more ex-post evaluation of the impact from PPP in urban transport projects in developing cities.

This Chapter presents an ex-post evaluation of the effects of private participation in BRT projects in Ecuador. As described in Chapter 3, Chapter 4 and Chapter 5, Quito pioneered the implementation of BRTs with Trolebus, Ecovia and Central Norte corridors, and Guayaquil followed with Metrovia T1, T3 and T2. These projects brought not only an improved rapid transit service, but a new organization of the urban transport sector including a new regulatory framework, formalization of operators and the creation of new transit authorities, among other components.

Regardless of the geographic proximity and similarities of the systems in both cities, the level of private participation differed, ranging from a traditional bid, build and public operation, to partnerships involving incumbent operators investing in vehicles, operating the system and thus, absorbing demand risk. The latter is a form of Public-Private Partnership (PPP) in the context of the contractual agreement between public and private sector that allows the private party to invest and manage the vehicle component. Given the differences in the vision of each project and the corresponding planning and implementation processes, it is important to understand their impact on the successes and failures of these systems, as well as the underlying reasons and root causes

for the chosen approaches. Also, it is of particular interest to understand why Guayaquil did not follow Quito's path in terms of private participation and system structure, amidst the success of the first corridor.

A key aspect that has not been studied in Ecuador is to what extent the level of private participation influenced the outcomes of the BRT systems. This chapter presents the first comprehensive evaluation of the six BRT lines, isolating the type of private participation to understand its particular influence in the project implementation. This is of specific importance in light of the exponential growth from Ecuadorian cities that generate urgent rapid transit requirements in the present and near future.

The primary objectives of this chapter are to develop an understanding of why these two developing cities choose different levels of private participation and to determine how successful they were in each case in the execution and operational stages. For this purpose, the subsequent sections are structured as follows: methodology, relevant project data, discussion of the project's performances and conclusions.

The results of this analysis show the complexity of project planning, implementation, and outcomes, as a function of different approaches to similar problems. The inclusion of incumbent operators produced two distinct outcomes, one of which resulted from a strategy that proved to be highly efficient.

## **6.1 Methodology**

Considering the number of projects in this research scope and information available from previous analyses (Dario Hidalgo & Carrigan, 2010; M. Siemiatycki, 2010; Touran et al., 2011), the case study approach was selected for this chapter. The methodologic approach is based in the technique detailed by Yin (2014). The analyses are based on data collected that includes previous research publications, public records, project reports, and conference proceedings. Several sources of information were utilized in order to confirm the validity of the data (i.e., feasibility studies, technical notes, institutional information: see Appendix C). The first phase of the analyses presents the relevant characteristics of each BRT corridor in chronological order; the second phase

examines the results of the projects as a function of the level of private participation and deviations from predicted and observed results (i.e., timeframe, budget and ridership) in search of patterns and their potential causes.

The case selection for this study took into consideration the BRT projects in Ecuador from 1993 to 2013. Projects that deviated from the standards of a BRT trunk line were not included (e.g., open access corridors or extension of existing corridors) in order to preserve the possibility to compare analogous scenarios. These projects provide a unique field of study since they have similar characteristics (trunk lines, feeder networks integration terminals, at level stations, prepaid entrance, intersection priority, fare structure, cities of similar size, geographic proximity, and comparable socio-political landscapes), something difficult to find in rapid transit projects. Nonetheless, the level of private participation in the two cities has fundamental differences. Quito leaned to the side of traditional public investment and operation, whereas Guayaquil towards private involvement in various elements of their systems.

The evaluation of these projects examines three stages: the planning phase, including potential restrictions in the environment and risk allocation, the second stage, the execution of the infrastructure, and finally the operation stage.

The analysis considers the variables of private capital expenses present in the project, “on time” delivery of infrastructure and equipment, “on budget” execution of infrastructure and equipment, the ability to meet the forecasted demand and finally the requirements for subsidies in the operational phase.

## **6.2 Relevant Project Data**

The characteristics of the BRTs analyzed in this chapter were previously described in Chapter 3, Chapter 4 and Chapter 5. Thus, only the relevant data is summarized in this subsection.

### **6.2.1 Trolebus**

This BRT project started operations in December 1995, (phase 1) (12 months from financing agreement signature). The forecasted demand of 105,000 trips per day for phase 1 and 150,000 with phase 2 was quickly attained and surpassed, and by the end of 1996 the system was transporting 170,000 passenger per day (Chauvin, 2007) prompting the addition of new trolleybuses. The final costs for Phase 1 and 2 of the project were reported at: 5.1M USD per km for 17 km trunk line (D. Hidalgo & Graftieaux). The operation of this corridor was planned as a public operation from the feasibility study, which already outlined the organizational structure of the operational entity.

### **6.2.2 Ecovia**

For this BRT corridor, the demand estimate for the year 2000 indicated 140,000 passengers per day (Gamboa et al., 2000). In November 2002, Ecovia started operations (excess of one-year delay; operation was expected by the end of 2000). However, the concession process wasn't completed, in part because of internal conflicts in the consortium (credit constraints, legal issues) (Chauvin, 2007). In February 2003, the concession agreement was signed and publicly acquired vehicles were privately operating by the consortium. Eventually, this corridor was operated by the municipality.

In spite of being conceptually planned for private operation this corridor could not successfully complete the intended PPP. Ecovia reports final costs of 2.1M USD per km (infrastructure 1.2M per km) and a daily ridership of 81,000 passenger in the trunk line (2006) (D. Hidalgo & Graftieaux, 2005; Menckhoff, 2005).

### **6.2.3 Central Norte (CN)**

For this BRT, the final costs of were 2.3M USD per km of infrastructure and 1M per km for vehicles, totaling 3.3M USD per km (D. Hidalgo & Graftieaux, 2005; Menckhoff, 2005). This project was advertised as a second generation of BRT systems, as operational speed was given priority in detriment to accessibility and presented major differences between demand estimates and actual ridership. The expected demand was 400,000 passenger per day (D. Hidalgo &



Graftieaux, 2005) but the actual ridership only reached 120,000 (2006). Contrary to Ecovia, this corridor was able to be operate with private buses for the time of the concession, although not without complications.

#### **6.2.4 Metrovia: T1 “Guasmo – Rio Daule”**

In this project, the feasibility study estimated an initial investment of 38.25M USD for the first trunk line, including vehicles at 11.9M. The daily ridership was estimated at 140,000 passengers (Arguello et al., 2004; von Buchwald, 2007). The daily demand was reported at 140,000 passenger for T1 (BRT Centre of Excellence; EMBARQ; IEA; SIBRT, 2017) (2013). The institutional information from 2011 indicates a cost of infrastructure of 2.2M USD per km (within 7% deviation of the feasibility study estimation).

This project and subsequent T3 and T2 have a similar approach for the execution: a traditional Design, Bid, Build, Multi-Prime (DBBMP). The execution was divided in major work groups (lanes, terminal stations, intermediate stations). The level of disaggregation within the traditional DBB is lower when compared to the projects in Quito, with larger contractors in charge of aggregated workgroups.

A consortium of historic operators was formed to provide the service and acquire the articulated buses. The contract was signed in 2005 with consortium “Metroquil” for a 12-year period. This trunk line was completed on time (Bids for infrastructure in January 2005 (Universo, 2004)) and operations started in July 2006 (von Buchwald, 2007)

#### **6.2.5 Metrovia: T3 “Bastion Popular – Centro”**

For this BRT, the daily ridership was estimated at 200,000 passengers (von Buchwald, 2007, p. 2). This system was expected to operate in by the end of 2007 (von Buchwald, 2007). The daily demand reports (BRT Centre of Excellence; EMBARQ; IEA; SIBRT, 2017) indicate 170,000 passenger for T3 (2014). The cost of infrastructure was reported by Metrovia in 2011 at 1.48M USD per km (\$1.62M USD/km was the estimation in the feasibility study). A consortium of historic operators was formed to provide the service and acquire the articulated buses. The contract

was signed in 2007 with consortium “Metro Bastion” for a 12-year period and operations started in May 2008. The inauguration date of this line fits in the schedule of the feasibility study that stated the implementation each trunk line within a 2-year frame.

### 6.2.6 Metrovia: T2 “Venticinco de Julio – Rio Daule”

In this case, the feasibility study estimated an initial investment of 87.58M USD including vehicles. However, the budget also includes two major overpasses for the city (50.78M). Without considering the overpasses, it was estimated at 36.8M USD (vehicles at 9.2M USD). The daily ridership was estimated at 120,000 passengers. This system was expected to operate by the end of 2008 (von Buchwald, 2007). A consortium of historic operators was expected to provide the service and acquire the articulated buses.

The start of work for this trunk line was postponed by the municipality. In July 2011, the civil works started (Guayaquil, 2011), the contract with consortium Metro Express was signed in 2012, and operations started in February 2013. The cost of infrastructure was reported at 4.18M USD per km (within 13% deviation of the feasibility study estimation). The daily demand was of 144,000 in 2014.

The six BRT projects described in this section are the result of large planning processes, that structured the networks of transit based upon trunk lines and present similar characteristics (except for Trolebus for vehicle technology). Table 6-1 presents a summary of the projects’ main characteristics.

**Table 6-1 BRT project characteristics**

<b>Project Name</b>	<b>Project type</b>	<b>Special features of the project</b>	<b>Length of trunk line [km.]</b>	<b>Observed total cost per km. [2017 million USD]</b>	<b>Private participation with capital expenses</b>
<b>Trolebus (1995)</b>	BRT trunk line with feeder	Trolleybuses & electrical infrastructure	11.35	\$10.3** \$1.9*	No
<b>Ecovia (2001)</b>	system, articulated vehicles	Central stations	9.00	\$4.2 \$2.4*	No
<b>CN (2005)</b>		2 lanes per direction	12.80	\$5.1 \$4.1*	Yes

<b>T1 (2006)</b>	Central stations	15.83	\$4.8 \$3.6*	Yes
<b>T3 (2008)</b>	Central stations	15.57	\$3.1 \$2.2*	Yes
<b>T2 (2013)</b>	Central stations + overpass sections	13.15	\$5.6 \$4.8*	Yes

\* Total cost without vehicle expenses

\*\* Project with electrical infrastructure and articulated electrical trolleybuses

### 6.3 Discussion of Project Performance

The corridors analyzed in this chapter are similar in their scope and infrastructure, thus presenting a unique scenario to analyze and compare factors that influenced their performance. The project contexts showed that the main factor of discrepancy is the level of private participation that derives from the initial conceptualization of each system.

The private participation is present in form of capital expenses for vehicle acquisition and fare collection system implementation. The first two projects (Trolebus and Ecovia) had no private funds for capital expenses. The projects that followed include private participation in the form of vehicle acquisition, representing between 25% and 31% of the total capital expenses.

This analysis considers the Project Delivery Method (PDM), the budget and schedule adherence, the ability to meet the estimated demand and finally the requirement for subsidies to include a perspective into the operational sustainability. Table 6-2 presents a summary of the variables identified for each project.

**Table 6-2 Variables for project analysis**

Project Name	Private funds	Operation	PDM	On time	On budget	Forecasted demand was met	Subsidies required
<b>Trolebus (1995)</b>	0%	Public	DBBMP	Yes	Yes	Yes	Yes
<b>Ecovia (2001)</b>	0%	Private (2005 takeover)	DBBMP	No	*	No	Yes
<b>CN (2005)</b>	30.3%	Private	DBBMP	No	**	No	Yes
<b>T1 (2006)</b>	31.2%	Private	DBBMP	Yes	Yes	Yes	No
<b>T3 (2008)</b>	25.3%	Private	DBBMP	Yes	Yes	No	No
<b>T2 (2013)</b>	26.6%	Private	DBBMP	Yes	Yes	Yes	No

\* Particular involvement of the municipality in the execution of infrastructure, this creates difficulty in the assessment of budget adherence.

\*\* No data available

The project delivery method (DBBMP) is similar for all six cases and does not present significant influence in the variables in study. However, the level of private participation, presents two considerations. In Ecovia and Central Norte, difficulties were encountered for vehicle acquisition and with historic operators who were allowed to maintain route services in direct competition with the new trunk lines, against the original operational design. This arrangement directly affected the demand for the new lines. A relevant point is that no evidence of interest from the private sector, other than incumbent operators, to participate in the projects was found. This raises a fundamental question of why there is no private interest in rapid transit projects in Ecuador from 1991 to 2013, in contrast to other sectors (e.g., highways).

In all five cases, the private consortium is a new entity with limited financial strength. In Quito, private participation resulted in conflicts and delays, but in Guayaquil there is no evidence of negative outcomes. The main difference is that Guayaquil identifies and overcomes the issues through the SPV with clear stakeholder interest alignment and enhanced transparency. The SPV formed increased credibility during the process. Banks who provided credit were brought in as stakeholders and enabled information access, an independent trust fund was implemented, and more importantly the influence of politics was reduced with a variety of sectors present in the SPV. Furthermore, the planning process in Guayaquil allocated a larger time frame for the implementation of the projects - 2 years for each trunk line.

Amidst the success of Trolebus, an all-public endeavor, and the failure of private participation in Quito, Metrovia proved that private participation of incumbent operators can be positive. The key points that enable positive results are the ability of the municipality to identify barriers and design solutions embedded in an SPV.

The process of interest alignment and genesis of an SPV required political leadership and technical competence. Unlike Quito, Guayaquil maintained one political line over time, permitting continuity in projects that surpass political periods. Ecovia showed that political changes in vision

can bring negative consequences for project execution, creating disruption of ongoing processes and institutional transformations.

The addition of incumbent operators decreases social conflicts and permits a viable solution to replace the existing fleet of the corridors, but it also adds risk of delay and hampers project performance, as the nature of the consortium lacks financial strength. Furthermore, in the case of Ecovia and CN, the replacement of parallel routes of incumbent operators was never fully completed, impacting the demand of the trunk lines. Operators that constitute at the same time trunk line and parallel routes operatives cannibalize their income and increase the costs. This short-term strategy lacks a vision of asset amortization and is probably the result of the outdated system focused on daily revenue, combined with weak Municipal control. The transition to corporate structures in the urban transport private sector has proved to be a very challenging process in Ecuador, unlike Colombia's Transmilenio system.

Nevertheless, private participation did provide an advantage to the Metrovia trunk lines, as evidenced by the lack of subsidies required for operation - while maintaining the same flat fare as Quito (0.25 USD). In this line, the role of the private sector becomes increasingly important after the execution of the infrastructure. In the lifecycle of the project, the investment in vehicles and maintenance costs can surpass infrastructure costs, placing a heavy risk on the operators. It is then of increasing importance that the structures of private operators reach basic formal business levels of strategy and operation, and probably the role of the public sector lies in establishing a roadmap for the partnership that steers this process. The SPV in Guayaquil presents such features, as it is the case of a second private partner called "ITOR" which stands for "technological integrator – operator of fare collection", that is in charge of operation design and control and fare collection.

In Quito, Trolebus and Ecovia are highly dependent on public funding. For the other projects studied, private participation in capital expenses for vehicle acquisition and operation has provided better operational results than public operation, considering that under similar conditions of fare and demand Guayaquil hasn't required subsidies. This particular issue raises the question of the potential role of the private sector in a BRT's efficient operation that reduces the requirements of public funding for operations, thus permitting more investment in new infrastructure in order to continue improving and expanding public transport. As of 2017, the

public entity in charge of corridors in Quito (EPMTTP, 2017) reported Municipal funding of 40M USD (40% of the operating budget), an amount equivalent to 8 km of new BRT trunk line. At such a rate, Quito could duplicate the existing BRT network in less than ten years, drastically improving coverage and travel times.

The key findings of this analysis are that the commonly used strategy of incorporating incumbent operators created two risks: potential delay in bus acquisition due to weak financial capabilities and potential for running parallel services in direct competition to the trunk lines. The mitigation of this risk with the use of an SPV that aligns interests of different stakeholders in the project and added transparency proved efficient in addressing these threats. The positive side of private participation has been its ability to not require operational subsidies, mainly due to a more efficient operation when compared to public processes. This efficiency can allow the expansion of rapid transit through public investment in fixed infrastructure (exclusive lanes, stations). This is of particular importance when considering that the external zones of these cities have shown rapid growth and are not served by rapid transit.

These findings complement previous research (Dario Hidalgo & Carrigan, 2010; Dario Hidalgo & Graftieaux, 2008; Lindau et al., 2014; Muñoz & Hidalgo, 2013) for Latin America and for Johannesburg (Venter, 2013), regarding the inclusion of private operators to mitigate conflict and formalize operators by providing elements that contributed to successful implementations through the SPV. Furthermore, the evidence shows that private participation permitted a more efficient operation that didn't required subsidies even with a low level fare scheme, adding a potential advantages to the findings of Willoughby (2013) for urban transport PPP.

## **6.4 Conclusions**

This chapter conducted an ex-post assessment of six BRT projects, which presented a unique homogenous scenario to weigh the impacts of private participation. It presents the first research effort seeking to understand the effects of private participation in Ecuador's rapid transit projects. This assessment led to five key findings: First, the incubation period was long and difficult because of financial, governance and social factors that influence the planning and design processes.

Second, the inclusion of incumbent operators can lead to financial difficulties due to weak financial strength as a result of the inherent nature of the consortiums. Third, the inclusion of incumbent operators can also lead to parallel operations that undermine the operation of the systems and affect the forecasted ridership. Fourth, an SPV can solve the two aforementioned issues with incumbent operators by a scheme that aligns interest and brings new stakeholders into a transparent process. Fifth, transportation planning in Ecuador proves to be difficult in the face of changing Municipal structures, weak control and very dynamic environments.

It was also observed that the commitment to historic operators in BRT has limited the advantages that a traditional PPP can bring (technology, knowhow) and probably represents a tradeoff between expected return on investment (low for current operators) and the sophistication a new entity can bring. Future research would be necessary to identify elements for BRT that will create a more suitable environment for PPPs, as no evidence of private interest was found (other than incumbents).

## Chapter 7

### **Conclusions and Guidelines for Rational Planning Processes and Effective Implementation**

This research focuses on the roots of the of the decisions that led to the planning and implementation (or lack thereof) of rapid transit systems in Ecuador. The documentation and analysis of these processes is quintessential for understanding how the current systems were realized and provides much needed evidence for future process improvement in Ecuadorian cities. In these cities and comparable settings, transit systems are critical for the vast majority of the population and a key element for changing the unsustainable trends of recent years (e.g., pollution, road safety, congestion, and modal split).

The analysis encompassed three stages: the design (factors that shaped the elements of the projects); the implementation (factors that determined the execution of the projects); and the effects of private participation (as a key factor that has influenced the planning, implementation and operation of the projects).

The first stage focused on the evaluation of the relative significance of the factors driving rapid transit planning processes, in order to understand the gaps between theory and practice. The first comprehensive analysis of all planned rapid transit projects in Ecuador was presented, based on a mixed-method comparing nine planning processes through quantitative and qualitative analyses. The quantitative approach was based on AHP and utilized three project components (alignment, size, and technology), for which five factors were assessed (demand, local conditions, financial, social and political). The results were contextualized and validated for each project with documentation from their planning processes.

The second stage focused on the identification and evaluation of the barriers that affected implementation. A case study approach, along with Best-Worst Scaling, was utilized in order to quantify and rank the barriers, and also to identify key mitigation measures. Previous analyses, conducted in other developing cities, focused primarily on BRTs and relied on qualitative methods. This research addresses the gaps in the analyses of barriers by considering three different



technologies (i.e., BRT, rail and gondola), including the planned but non-implemented projects. Moreover, a novel methodology to derive an objective ranking of barriers was developed to complement the previously employed qualitative methods.

The third stage conducted an ex-post assessment of six BRT projects, based on a case-study approach. These projects presented a unique homogenous scenario to weigh the impacts of private participation. The analysis presented the first research effort seeking to understand the effects of private participation in Ecuador's rapid transit projects.

## **7.1 Conclusions**

The analysis of the planning processes showed five key results: 1) Each project was unique and external factors introduced a varying degree of complexity into each planning process; 2) The systems' alignments and sizes were mostly driven by demand and local conditions (rational process); 3) The main factor driving technology selection has evolved over time from system demand to political factors (political bargaining approach); 4) Negative economic conditions had a large influence on the factors of all project components; and 5) There is a lack of rational alternative evaluation and an absence of corresponding tools/guidelines in Ecuador.

Results from the analysis of the implementation processes indicated the top tier of critical barriers is composed of 1) Lack of political leadership, commitment or continuity; 2) Underestimation of implementation complexities; 3) Political frictions; and 4) Rushed planning processes. In addition, it was found that critical barriers are not technology specific, but rather endemic to the planning process.

This assessment of private participation in past BRT projects led to five key findings: 1) The incubation periods of these projects were long and difficult because of financial, governance and social factors that influence the planning and design processes; 2) The inclusion of incumbent operators can lead to financial difficulties due to weak financial strength as a result of the inherent nature of the consortiums; 3) The inclusion of incumbent operators can also lead to parallel operations that undermine the operation of the systems and affect the forecasted ridership; 4) An SPV can solve the two aforementioned issues with incumbent operators by a scheme that aligns interest and brings new stakeholders into a transparent process; and 5) Transportation planning in

Ecuador proves to be difficult in the face of changing Municipal structures, weak control and very dynamic environments. It was also observed that the commitment to historic operators in BRT has limited the advantages that a traditional PPP can bring (technology, knowhow) and probably represents a tradeoff between expected return on investment (low for current operators) and the sophistication a new entity can bring.

Based on the analysis of the aforementioned findings, the next section presents a concise description of recommended guidelines for future rapid transit projects.

## **7.2 Guidelines**

The analysis of the planning processes revealed some practices that contributed to a more rational planning process. Based on these findings, the following guidelines are recommended for future projects, along with conventional best practices:

1. Include and evaluate the decision-maker expectations in the planning process, but do not discard the study of feasible project elements (i.e., technology and alignment);
2. Perform a lifecycle cost analysis for the various feasible technology alternatives considering the specificities of the project's environment (i.e., do not discard alternatives based on general technology characteristics);
3. Use Multi-Criteria Decision Analysis Tools for the evaluation of feasible alternatives to ensure objective assessment.
4. Transfer the demand risk to the private sector to promote a thorough analysis of feasible alternatives (alignment and technology);

The results showed that processes with rational alternative evaluations can be conducted, however the challenge is to create the conditions (incentives and normative) to promote them, especially to accommodate the political factor.

In terms of implementation, seven key mitigation measures were identified from past projects:

1. Increase the private role in the procurement strategy (e.g., DBFOM);
2. Generate public opinion monitoring;
3. Connect the social, political and technical perspectives;

4. Increase community input during planning;
5. Adapt projects features to community input (when applicable);
6. Aim at starting construction before the end of political cycles (phased implementation);
7. Focus on the implementation of one trunk line at a time.

These mitigation measures were matched to specific barriers in order to characterize their viability. These connections suggest that a bundle of key mitigation measures is needed to address a particular barrier.

The critical dependence of implementation on political support fostered short-term planning based on political cycles in detriment to long-term visions. The senior technical teams highlighted the relevance of external supervision to apply long-term planning independent of political cycles (not political input). For this, community input and transparency emerge as paramount elements. These findings align with previous results from developing cities, confirming the transferability of results at an aggregate level, but also showed that the barriers and corresponding mitigation measures can be context specific and thus, should be evaluated accordingly.

Nonetheless, the results for the planning and implementation stages also showed that private participation was a key factor that can improve the processes under particular conditions. In this line, the following guidelines are derived:

1. The use of an SPV allows for the alignment of interests and brings new stakeholders into a transparent process.
2. The composition of the governing body of the SPV is key for reaching the intended objective.
3. The positive aspects of private participation in the form of incumbent operators (i.e., traditional bus operators of developing cities) limits the advantages of such procurement strategies.

### **7.3 Contributions**

This research presented the first comprehensive analysis of all planned rapid transit projects in Ecuador (implemented and not implemented). Previous efforts were tangential to Ecuadorian projects and focused on a regional scale and on the project build characteristics, rather than the processes of design and implementation. An extensive effort of collecting project documentation (i.e., feasibility studies, technical notes, contractual documents) was conducted and provides relevant data for future research.

A novel framework was proposed and applied for the analysis of planning and implementation processes. Previous research focused on qualitative analyses, however the applied mixed-method approach evaluates the processes not only from a qualitative perspective, but also from a quantitative one. For this, two quantitative methods were adapted and applied (AHP and BSW) to field collected interview and survey data, in order to compare and contrast the planning and implementation processes from an objective perspective. This framework is transferable for comparable research in other settings (e.g., neighboring countries), as the methodology can be applied to other rapid transit projects. In addition, measures to strengthen this framework were outlined for future research.

The results provide unprecedented information regarding the evolution and relative importance of the factors that shape the planning process and the ranking of barriers that hinder implementation, along with a deeper analysis of the effects of private participation. To date, this is the only comprehensive analysis of all rapid transit projects and provides evidence for future process improvements. Moreover, it is expected that this research will promote and support future efforts for rapid transit projects in Ecuador.

### **7.4 Limitations and Future Research**

The limitations of this research were described in detail in Chapter 4, Chapter 5 and Chapter 6, to provide context for the interpretation of the corresponding results and for future improvements. Overall, these limitations can be grouped in two main categories. First, the inherent nature of the responses to the interviews and surveys involves individual and potentially subjective judgements

of senior technical staff. Second, there is a degree of overlap and interconnection that applies to factors that influence the design and barriers for the implementation. Best efforts were made to address these limitations, including contrasting the quantitative results against project documentation and between project elements, using mathematical procedures to assess the congruence of results (i.e., consistency index in AHP), analyzing the results as orders of magnitude and direction, and interpreting the results within the context of each project.

The results of this research uncovered five new streams of research. First, the political factor was quintessential, not only for prioritizing technology, but for the progress or stagnation of several projects, and the underlying motivations for these political preferences are yet to be identified, in particular the examination of the role played by the state and perception of existing rapid transit projects (operational and physical) with respect to the political feasibility of implementing new similar systems (e.g., how does the image of current BRT systems (poor quality) hinder the advancement of similar projects?).

Second, the underestimation of complexities (optimism bias) promoted the implementation of at least three projects (Central Norte, Cuenca Tranvia and Quito Subway), but the costs remain unclear (e.g., are unbiased projects left in archive? What are the differences between estimated and actual results for budget and time? etc.). Moreover, the decision-makers' choice to prioritize new and more expensive technologies requires deeper investigation, since it is not obvious how the high capital and operating costs associated with the rail and gondola projects are aligned with their highly constrained budgets.

Third, it appears necessary to identify elements for BRT that will create a more suitable environment for PPPs, as no evidence of private interest was found (other than incumbents).

Fourth, these results raise questions regarding the long-term sustainability of publicly operated BRTs and the constraints that operational subsidies can create to new capital investments, as Municipal budgets are increasingly redirected towards operations. It becomes relevant to study if private operation can improve the long-term sustainability of the BRT systems in Ecuador. Also, in light of the requirements of subsidies for public operation, the evaluation of modes that can provide better operational efficiencies is important (LRT, BHLS) and identify if the systems would benefit by transforming to rail configurations as they reach the end of their lifecycles.

Fifth and final, the specific model and framework of the successfully implemented SPV of Guayaquil (Metrovia) is of interest for future research. Exploring these issues should provide further understanding of the complex transit planning process in Ecuador.

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**Appendix A**  
**Survey Instrument for AHP process**

**Date:**

**1. Base Information:**

1. Please indicate the project's name and location:
2. Please provide a brief description of the project
3. Name of agency in charge of the project planning:
  - a. Which was the direct authority above each agency?  
 National planning agency  
 Mayor's office  
 City council  
 Other

4. Please indicate when the planning process started (month and year)?   Month                      Year

Planning process start is considered the problem definition by the technical team.

5. Were consultants hired to develop or assist the planning process?           yes                       no 
  - a. Describe the role of the consultants

6. Did the project have international cooperation (e.g., UNDP, IDB):           yes                       no 
  - a. If yes, please describe the relevance of this cooperation for the project

7. Were the procurement and implementation strategies included in the preliminary planning process: yes                       no 
  - a. If yes, please describe the strategy.

b. If not, describe why not.

8. Was a communication strategy developed as a part of the planning process? yes  no   
a. If yes, please describe the strategy and the importance to the implementation:

9. Please indicate if the project was implemented? yes  no   
a. Was it implemented on time? yes  no  (definition of on time >2-month delay)  
b. Was it implemented on budget? yes  no  (definition of on budget >10%)  
c. If not, please describe the main reasons?

## 2. Mapping the Decision Process

The planning phase includes the preliminary engineering design until the final definition of alignment, size and technology.

### 2.1. Decision to advance to detailed engineering

10. Please indicate who made the decision to advance the project to detailed engineering?

- Mayor/City council
- Other, please explain

11. Please indicate based on which information this decision was made? *Check all that apply*

- Feasibility studies
- Community/social input
- Political input
- Financial input
- Other, please explain

12. Please indicate how the planning team presented the information to the decision-makers (*Check all that apply*):

- Formal reports
- Formal meetings
- Informal meetings
- Other

13. Please indicate how often and on which format were the decision-makers informed of the advances in the preliminary engineering studies  
(Check all that apply):

- |                                   |                                           |
|-----------------------------------|-------------------------------------------|
| <input type="checkbox"/> weekly   | <input type="checkbox"/> Formal report    |
| <input type="checkbox"/> monthly  | <input type="checkbox"/> Formal meeting   |
| <input type="checkbox"/> annually | <input type="checkbox"/> Informal meeting |
| <input type="checkbox"/> Other    | <input type="checkbox"/> Other            |

14. Please indicate if the original technical recommendation suffered substantial changes compared to the implemented project.

- Yes  No

a. What modifications were made to the original plan?

- i. Technology  Yes  No  
Please explain
- ii. Alignment  Yes  No  
Please explain
- iii. Size  Yes  No  
Please explain

15. Please describe the rationale behind these decisions.

16. From the list below, please describe the key factors that led the project to implementation or non-implementation (*Check all that apply*)?

- b.  Technical
- c.  Political
- d.  Social
- e.  Financial
- f.  Other

17. Please describe the key barriers that the project faced regarding implementation?

- a.  \_\_\_\_\_
- b.  \_\_\_\_\_
- c.  \_\_\_\_\_
- d.  \_\_\_\_\_

18. Please describe the key drivers that permitted project implementation?

- e.  \_\_\_\_\_
- f.  \_\_\_\_\_

*Prompt the following items after the initial response to assess the importance of each driver.*

- g.  Communication strategy?
- h.  Project champion?
- i.  Interaction with decision-makers?
- j.  Interaction with stake-holders?

## 2.2. Decision for evaluation of alternatives

19. Please indicate if the engineering studies included evaluation of alternatives

- k.  Yes
- l.  No, please explain why

20. If yes, which alternatives were evaluated (*how many and a brief description*)?

21. Please indicate which authority made the decision for the evaluation of alternatives?

- Technical team

- Mayor/City council
- Other, please explain

22. Please indicate if decision-makers were informed of the alternatives under evaluation.

- m.  Yes
- n.  No, please explain why

23. Please indicate if the input of decision-makers was included in the evaluation of alternatives.

- o.  Yes, please explain why
- p.  No, please explain why

24. Please indicate if other stakeholders were informed of the alternatives under evaluation.

- q.  Yes
- r.  No, please explain why

25. Please indicate if the input of other stakeholders was included in the evaluation of alternatives.

- s.  Yes, please explain why
- t.  No, please explain why

2.3. Decision for alternatives of design

26. Please indicate if the engineering studies included initial alternatives that were discarded.

- u.  Yes, please explain why
- v.  No, please explain why

27. Please indicate if any alternatives were discarded due to external factors?

- yes, describe the factors
- no

28. Please indicate if the input of stakeholders or decision-makers was included in the analysis of initial alternatives?

- w.  Yes, please explain why
- x.  No, please explain why

#### 2.4. Decision for initial processes

29. Please indicate which authority decided to start the process of transit planning?

- y.  Mayor/city council
- z.  Technical team
- aa.  Other

30. Please indicate which authority defined the goals of the transit system?

Goal is defined as a broad primary outcome of the system

- bb.  Mayor/city council
- cc.  Technical team
- dd.  Other

31. Please indicate which authority defined the objectives of the transit system?

Objective is defined as a measurable step of the system

- ee.  Mayor/city council
- ff.  Technical team
- gg.  Other

32. Please indicate if the input of stakeholders or decision-makers was included in the analysis of initial alternatives?

- hh.  Yes, please explain why
- ii.  No, please explain why

#### 2.5. Project inception



33. Please describe the main motivation for the project (single most significant reason)?
- jj. Describe the rationale behind this decision?
  - kk. Specify which authority made this decision to initiate the project?
  - ll. Specify when was the decision made (*month and year*)? Month            Year
  - mm.            Describe major factors the influenced this decision
34. Please indicate if any initial constrains limited the project planning (*Check all that apply*)? yes  no
- Financial threshold
  - Technology ex-ante definition
  - Alignment ex-ante definition
  - Other, please explain
- nn. Please describe who defined the constraints
- oo. Please describe how they affected the project

**2.6. Internal factors**

35. Please describe the main local conditions/factors that were taken into consideration (*Check all that apply*)?
- Topography
  - Street network
  - Other, explain
- pp. Please describe if these factors had major influence in project features (such as limiting technology choices)
36. Please indicate what travel demand factors were taken into consideration (*Check all that apply*)?
- Corridor current ridership
  - Forecasted future ridership
  - Cultural characteristics
  - Other, explain

qq. Describe if these factors had major influence in the project features (*see textbox in section 4.1 for definitions*)

- Technology
- Size
- Alignment
- Other, explain

rr. What type of modelling was done?

- Traditional four step model
- Other, explain

ss. Was any specific adaptation to the model considered for the local context?

## 2.7. External factors

37. Please describe if external factors influenced the project planning (*Check all that apply*)? yes  no

- Political
- Financial
- Social
- Other: Explain

tt. Which political factors influenced the planning process?

Political factors are governmental policies, political decisions or practices that influenced the project

Describe the influence

uu. Which financial factors influenced the planning process?

Financial factors are policies, decisions or practices related to the monetary resources for the project (e.g. founding, credit)

Describe the influence

vv. Which social factors influenced the planning process?

Social factors are circumstances, characteristics or interactions with groups that are affected by the project

Describe the influence

ww. Which institutional factors influenced the planning process?

Institutional factors are policies, practices or characteristics of the institutions that were involved in the project

Describe the influence

### 3. Stakeholders and transparency

38. Please describe the goals of the stakeholders

- xx. Mayor
- yy. City council
- zz. Incumbent
- aaa. Financiers

39. Please describe the risks to the stakeholders

- bbb. Mayor
- ccc. City council
- ddd. Incumbent
- eee. Financiers

40. Please indicate if the stakeholders had access to the technical information of the project (e.g. feasibility study)

- fff. Mayor: yes  no  If no, explain why
- ggg. City council: yes  no  If no, explain why
- hhh. Incumbent: yes  no  If no, explain why
- iii. Financiers: yes  no  If no, explain why
- jjj. Public in general: yes  no  If no, explain why

41. Please indicate if there was the planning phase included a risk assessment of the project implementation phase.

- kkk.  Yes, please describe the major risk identified at this stage:
- lll.  No, please explain why there was no risk assessment

42. Please describe the major risks that the project faced for its implementation.

- mmm.
- nnn.

43. At which point in the political cycle did the planning started

- ooo. Year 1
- ppp. Year 2
- qqq. Year 3
- rrr. Year 4
- sss. Year 5

44. At which point in the political cycle did the implementation started (*applicable only for projects that were implemented*)

tth. Year 1

uuu. Year 2

vvv. Year 3

www. Year 4

xxx. Year 5

#### 4. Quantification of external factors AHP

##### 4.1. Pairwise comparison of criteria for project implementation

Please rate the comparison between two factors using the following scale

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
2	Weak importance	
3	Moderate importance	Experience and judgment slightly favor one activity over another
4	Moderate	
5	Strong importance	Experience and judgment strongly favor one activity over another
6	Strong plus	
7	Very Strong/demonstrated importance	Activity favored very strongly over another; demonstrated in practice
8	Very very Strong importance	
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation

*Technology* refers to specific vehicles, their mechanical attributes and the right of way (RoW).

*Alignment* refers to the route that the system utilizes between the two terminal stations.

*Size* refers to the physical scope of the system and its components. specifically in terms of number of intermediate

Example: For the project alignment: what is the relative importance of demand versus financial factors.

In this case, the number 7 is selected for demand. This means that the influence of demand in the preliminary engineering phase is favored very strongly over financial factors. This statement can be demonstrated in practice (e.g. 7 times more important than finance).

Criteria	Alignment																Criteria	
Demand	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Financial

Criteria	Alignment																Criteria	
Demand	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Financial
Demand	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Local conditions
Demand	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Political
Demand	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Social
Financial	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Local conditions
Financial	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Political
Financial	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Social
Local conditions	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Political
Local conditions	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Social
Political	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Social

Criteria	Size																Criteria	
Demand	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Financial
Demand	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Local conditions
Demand	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Political
Demand	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Social
Financial	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Local conditions
Financial	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Political
Financial	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Social
Local conditions	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Political
Local conditions	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Social
Political	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Social

Criteria	Technology																Criteria	
Demand	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Financial
Demand	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Local conditions
Demand	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Political
Demand	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Social
Financial	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Local conditions
Financial	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Political



Financial	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Social
Local conditions	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Political
Local conditions	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Social
Political	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Social

**4.2. Pairwise comparison of project components with respect to their impact in project implementation**

Please indicate the importance of project components with respect to the project implementation probability.

How important was the alignment in the project implementation in comparison to technology? Equal, Strongly more important?

Criteria	Size																	Criteria
Alignment	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Size
Alignment	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Technology
Size	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Technology

## Appendix B

### Survey Instrument for BWS process

This research seeks to identify the key barriers for rapid transit implementation. The survey requires to identify the MOST and LEAST relevant barriers for the implementation of these projects. For this the study has identified barriers in the literature, which are enumerated and defined in the following table. We ask you to please take a moment to read the key barriers and definitions.

Category	Barriers	Definition
<b>Institutional</b>	16. Complex institutional processes and coordination	Institutional processes and coordination generate project abnormal delays or changes.
	17. Inadequate legislation/framework	Legislation does not support the development of the project (e.g., lack of competencies).
	18. Complex and lengthy expropriation and environmental processes	Resources required surpassed normal expectation (time, staff, funding) and result in large delays or archive.
<b>Technical</b>	19. Limited technical capabilities	Insufficient technical staff, experience or equipment to develop the project.
	20. Underestimation of implementation complexities (optimism bias)	Underestimation of the requirements to reach project implementation (e.g., time, finance, opposition).
	21. Inadequate management of competing modes	Competing modes could not be satisfactorily managed (e.g., prevent direct competition).
	22. Lack of community participation	Community input was not considered or did not play a relevant role in the project.
	23. Inadequate or insufficient project promotion	Project was not promoted in the community or promotion did not reach large audiences.
<b>Political</b>	24. Lack of political leadership, commitment or continuity	Political leader (Mayor) did not oversee or promote the project; changes in leadership (new cycle)
	25. Political frictions	Resistance or opposition from different government levels (e.g., lack of national government support)
	26. Lack of stakeholder alignment	Stakeholders had conflicting interest that were not addressed in the project.
	27. Rushed planning processes	

		Technical processes' times were reduced from standard timing ranges
<b>Social</b>	28. Opposition of incumbent operators and other affected parties	Concise actions from incumbents to prevent project implementation
	29. Bias towards road capacity improvements	Concise actions to demote the project in favor of road expansion.
<b>Financial</b>	30. Inadequate funding	Lack of funding sources or required coordination

Section 1

From the list below, please select the MOST and LEAST relevant barriers for rapid transit project implementation (1/9)		
Most relevant		Least relevant
	Inadequate management of competing modes	
	Lack of political leadership, commitment or continuity	
	Complex institutional processes and coordination	
	Limited technical capabilities	
	Inadequate funding	

From the list below, please select the MOST and LEAST relevant barriers for rapid transit project implementation (2/9)		
Most relevant		Least relevant
	Rushed planning processes	
	Lack of community participation	
	Underestimation of implementation complexities	
	Lack of stakeholder alignment	
	Inadequate legislation/framework	

From the list below, please select the MOST and LEAST relevant barriers for rapid transit project implementation (3/9)		
Most relevant		Least relevant
	Complex and lengthy expropriation and environmental processes	
	Bias towards road capacity improvements	
	Inadequate or insufficient project promotion	
	Opposition of incumbent operators and other affected parties	
	Political frictions	

From the list below, please select the MOST and LEAST relevant barriers for rapid transit project implementation (4/9)		
------------------------------------------------------------------------------------------------------------------------	--	--

Most relevant		Least relevant
	Limited technical capabilities	
	Opposition of incumbent operators and other affected parties	
	Inadequate legislation/framework	
	Lack of political leadership, commitment or continuity	
	Underestimation of implementation complexities	

From the list below, please select the MOST and LEAST relevant barriers for rapid transit project implementation (5/9)		
Most relevant		Least relevant
	Complex institutional processes and coordination	
	Lack of stakeholder alignment	
	Bias towards road capacity improvements	
	Inadequate funding	
	Lack of community participation	

From the list below, please select the MOST and LEAST relevant barriers for rapid transit project implementation (6/9)		
Most relevant		Least relevant
	Inadequate or insufficient project promotion	
	Inadequate management of competing modes	
	Rushed planning processes	
	Political frictions	
	Lack of political leadership, commitment or continuity	

From the list below, please select the MOST and LEAST relevant barriers for rapid transit project implementation (7/9)		
Most relevant		Least relevant
	Complex and lengthy expropriation and environmental processes	
	Limited technical capabilities	
	Rushed planning processes	
	Complex institutional processes and coordination	
	Inadequate legislation/framework	

From the list below, please select the MOST and LEAST relevant barriers for rapid transit project implementation (8/9)		
Most relevant		Least relevant
	Bias towards road capacity improvements	
	Underestimation of implementation complexities	
	Inadequate management of competing modes	
	Complex and lengthy expropriation and environmental processes	
	Inadequate funding	

From the list below, please select the MOST and LEAST relevant barriers for rapid transit project implementation (9/9)		
Most relevant		Least relevant
	Inadequate or insufficient project promotion	
	Lack of stakeholder alignment	
	Opposition of incumbent operators and other affected parties	
	Lack of community participation	
	Political frictions	

Section 2

1. Please describe the most relevant barrier for the implementation of rapid transit projects and how it affected the project

-----  
 ---  
 -----  
 ---  
 -----  
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2. Please describe the most effective measures to overcome this barrier

-----  
 ---  
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Section 3

Please select the projects in which you have participated from the list below.

- Trolebus
- Ecovia
- Central Norte
- Metrovia (T1, T2, T3)
- Metrovia (T4, T5, T6, T7)
- BRT de Cuenca
- Tranvia de Cuenca
- Metro de Quito
- Quito Cables
- Extension Norte del Trolebus

## Appendix C

### Primary Technical Documentation Sources

Document name (Spanish) and translation	Year	Project
“Proyecto Trolebus para la Ciudad de Quito: Estudio de Factibilidad” - Project Trolebus for the City of Quito: Feasibility Study.	1991	Trolebus
“Plan de Racionalización del Transporte Público Masivo de la Ciudad de Guayaquil” – Plan of Rationalization of Mass Transit for the city of Guayaquil.	2004	Metrovia
“Conflictos y gobierno local: el caso del transporte urbano en Quito” - Conflicts and local government: the case of Quito urban transit.	2007	BRTs in Quito
“Memorias del Transporte. Quito” Memories of Transport, Quito.	2000	BRTs in Quito
“Estudios para el diseño conceptual del sistema integrado de transporte masivo de Quito y factibilidad de la primera línea del metro de Quito” – Studies for the conceptual design of Quito’s mass transport integrated system and the feasibility of the first subway line.	2010	Metro de Quito
“Estudio de definición de la red primaria de transporte de la ciudad de Cuenca y factibilidad de su primera línea. Cuenca” – Study for the definition of the primary transport network of Cuenca and the feasibility of the first line.	2011	Tranvia Cuenca
“Contrato de consultoría para diseño e ingeniería de la primera línea del metro de Quito” – Contract for the consulting services for the design and engineering of Quito’s first subway line.	2011	Quito Subway
“Encuesta domiciliaria de movilidad (EDM11) del distrito metropolitano de Quito” - Household mobility survey (EDM11) of the metropolitan district of Quito.	2012	Metro de Quito
“Estudio de Impacto Ambiental de la Primera Línea del Metro de Quito” – Environmental Impact Study for Quito’s First Subway Line”	2012	Metro de Quito
“Diagnóstico Estratégico del Distrito Metropolitano de Quito - Eje de la Movilidad” – Strategic Diagnostic of Quito – Mobility Axis.	2014	Quito Rapid Transit
“Estudio de demanda del sistema de transporte por cable del DMQ: Modelo de elección modal” – Demand study for the cable transport system in the DMQ: Mode-choice model	2015	Quito Cables
“Anteproyecto del Corredor Labrador – Carapungo” – Feasibility Study of the Corridor Labrador – Carapungo”	2015	Trolebus north-extension
“Estudio de viabilidad preliminar del proyecto del sistema de transporte por cable de Quito” – Preliminary study of the feasibility of the cable transport system for Quito	2015	Quito Cables

<p>“Estudio de Factibilidad de un Sistema de Transporte Masivo Alternativo para la Ciudad de Guayaquil: Transporte Aero-Suspendido – Aerovia” – Feasibility Study of an Alternative Mass Transit System for Guayaquil: Aero-Suspended Aerovia”</p>	<p>2015</p>	<p>Aerovia</p>
<p>“Estudio Preliminar para la Implementacion de Tres Lineas de Cable en los Barrios Altos del Distrito Metropolitano de Quito” – Preliminary Study for the Implementation of Three Lines of Cable in the High Neighborhoods in the Metropolitan District of Quito.</p>	<p>2015</p>	<p>Quito Cables</p>

## **Appendix D**

### **AHP General Procedure Application**

The AHP procedure utilized in this research is outlined in this section. This method is applied to determine the weights of the criteria used for the project's planning. For the cases under study, a single alternative (i.e., the recommended alternative) is analyzed, hence, the structure of the hierarchy is simple, and the set of alternatives is  $X = \{A1\}$ , where A1 is the alternative selected for the project.

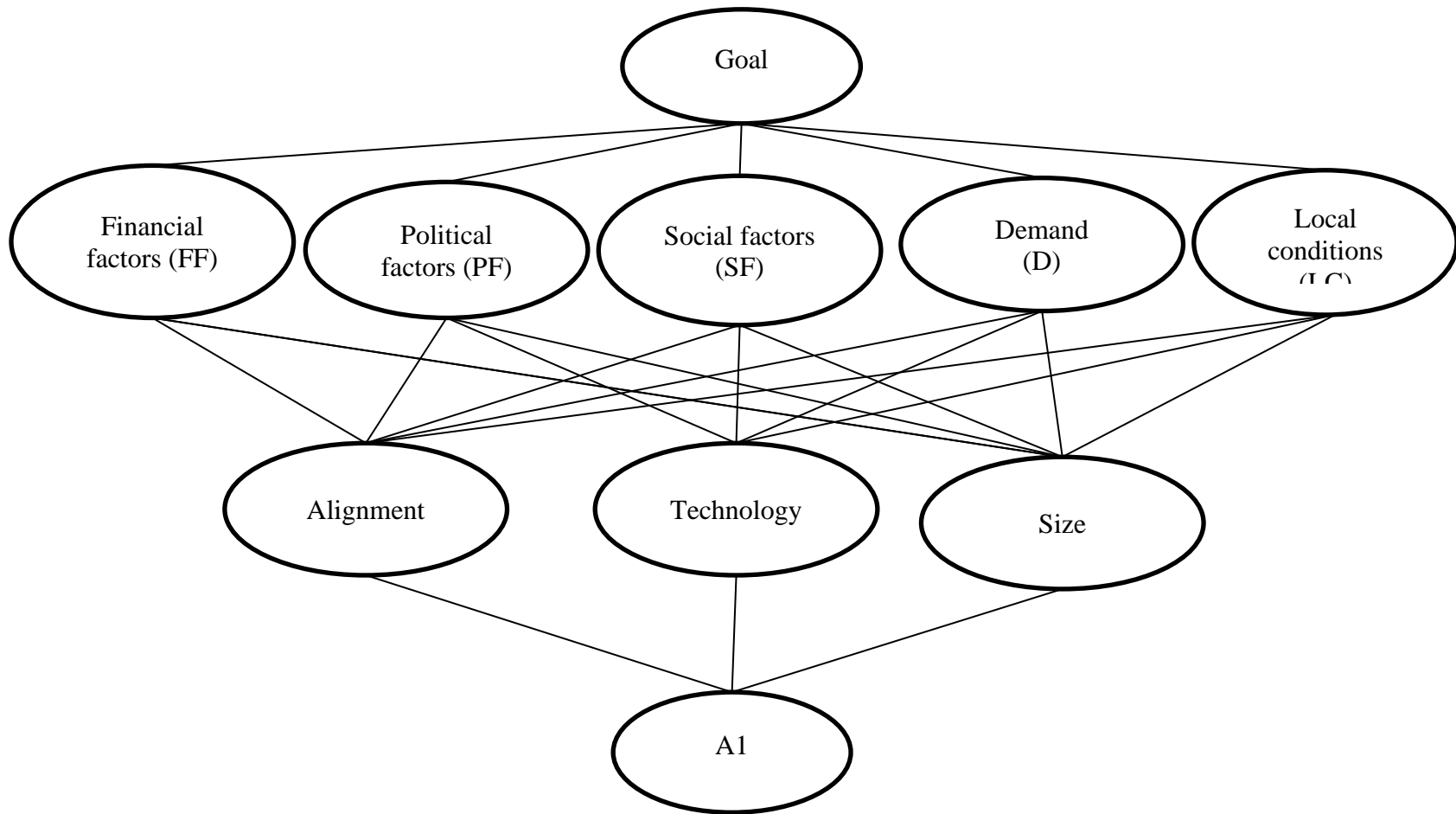
It is important to note that the factors (i.e., criteria) are intangible. Thus, a pairwise comparison is appropriate to evaluate their relative importance. Therefore, the fundamental scale of AHP is used to evaluate the alternative under each factor.

In order to derive the vector of weights, the simplest approach is to evaluate each factor through pairwise comparison of the impact it had on the planning process. The evaluation scale can be interpreted as a continuum from 9 to 1/9 for each factor. For instance, if criteria 1 is considered to have "strong importance" over criteria 2, then it will be assigned a "5", thus criteria 2 will be assigned "1/5" with respect to criteria 1. However, it is easier to understand the evaluation in a scale of 1 to 9 and then allocate the corresponding reciprocal in the pairwise comparison matrix.

The project is decomposed into three components. These project components are: alignment, size and technology. Figure D-1 presents the hierarchy with the additional criteria and components.

Once the factors, project elements and alternative are structured in a hierarchy, it is possible to continue with the pairwise comparisons. This procedure utilizes a pairwise questionnaire to compare two criteria at a time. In this case, each project component will have a corresponding questionnaire that includes all the criteria under study.





**Figure D-1 Hierarchy structure for single alternative, five criteria and three project components**

Table D-1 presents an example of the scores in a pairwise comparison of factors for a given project component (e.g., alignment), where D is demand, LC is local conditions, FF financial factors, PF political factors and SF social factors. The scores for each pairwise comparison are highlighted in bold numbers. For instance, the first row of Table D-1 indicates that demand (patronage) has a “very strong” (7) influence in the design of the alignment in comparison to the influence of finance factors.

**Table D-1 Questionnaire of pairwise comparison of criteria for project alignment**

Criteria	Alignment																Criteria	
D	9	8	<b>7</b>	6	5	4	3	2	1	2	3	4	5	6	7	8	9	FF
D	9	8	7	6	<b>5</b>	4	3	2	1	2	3	4	5	6	7	8	9	LC
D	9	8	7	6	5	4	<b>3</b>	2	1	2	3	4	5	6	7	8	9	PF
D	9	8	7	6	5	4	<b>3</b>	2	1	2	3	4	5	6	7	8	9	SF
FF	9	8	7	6	5	4	3	2	1	2	<b>3</b>	4	5	6	7	8	9	LC
FF	9	8	7	6	5	4	3	2	<b>1</b>	2	3	4	5	6	7	8	9	PF
FF	9	8	7	6	5	4	3	2	1	2	<b>3</b>	4	5	6	7	8	9	SF
LC	9	8	7	6	5	4	<b>3</b>	2	1	2	3	4	5	6	7	8	9	PF
LC	9	8	7	6	5	4	3	2	1	2	<b>3</b>	4	5	6	7	8	9	SF
PF	9	8	7	6	5	4	3	2	1	2	3	4	5	6	<b>7</b>	8	9	SF

From Table D-1 a table of pairwise comparison is constructed as presented in Table D-2. This table is named *Matrix A<sup>(a)</sup>*. The superscript “a” is added to indicated that the matrix corresponds to the alignment component of the project.

**Table D-2 Matrix A(a) of pairwise comparison for alignment**

	Demand	Finance	Local Cond.	Political	Social
Demand	1	7	5	3	3
Finance	1/7	1	1/3	1	1/3
Local Cond.	1/5	3	1	3	1/3
Political	1/3	1	1/3	1	1/7
Social	1/3	3	3	7	1

Table D-2 permits calculation of the principal eigenvalue and corresponding eigenvector with the methodology presented in Section 4.1.2.

The principal eigenvalue for this matrix is 5.4235 and the corresponding eigenvector is (0.833 ; 0.107 ; 0.227 ; 0.119 ; 0.478). From this information the weights are derived by normalizing the principal eigenvector. Thus, we can write the priority vector  $W^a$  as:

$$W^a = \begin{Bmatrix} 0.47 \\ 0.06 \\ 0.13 \\ 0.07 \\ 0.27 \end{Bmatrix}$$

The results of the normalized eigenvector are also shown in Table D-3 in a percentage format.

**Table D-3 Normalized eigenvector for alignment**

	Weight
Demand	47%
Finance	6%
Local Cond.	13%
Political	7%
Social	27%

The above process is repeated for the remaining project components: technology and size. The results for the analysis of individual project components (alignment, technology and size) show the relative importance of each factor for each of the three components. In this example, demand and local conditions are predominant, whereas finance, social support and political support have important roles in size, alignment and technology, respectively.