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CLIMATE ADAPTATION IN INFRASTRUCTURE PLANNING

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**The Impact of Financial Mechanisms on  
Acceleration of Urban Transportation  
Systems Adaptation to Climate Change  
- Barcelona Case Study -**

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# ABSTRACT

Urban transportation systems face increasing pressure to adapt to the challenges posed by climate change. The response to these challenges is exceedingly time-consuming. In order to achieve effective response to these challenges, climate adaptation projects must accelerate. The aim of this study is to compare the relationship between financial mechanisms and the acceleration between bus electrification projects in Barcelona, Spain. Literature suggests that multiple finance sources accelerate projects more effectively than a single source, the research contrasts this with empirical findings. Two projects are analyzed: the Electrobus project and the TB Clean Urban Transport Fleet Renewal project. While theory predicts a faster pace of acceleration for projects with multiple finance sources, the TB Clean Urban Transport Fleet Renewal project, funded by a single large loan, demonstrated more efficient progress compared to the Electrobus project, which relied on smaller grants and financing. The analysis reveals that strict financial regulations and economic crises can impede project timelines, as evidenced by the two-year delay in the Electrobus project. Both projects successfully reduced greenhouse gas emissions, but the Electrobus project provided precise data on emissions reduction, while data for the TB Clean Urban Transport Fleet Renewal project was less precise. Despite these differences, both projects underscore the importance of sustainable urban transportation initiatives in mitigating climate change impacts. The study concludes by highlighting the need for further research to explore the interplay between financial mechanisms and project acceleration in urban transportation contexts, considering factors such as funding size, regulatory constraints, and project complexity. Future research endeavors could offer valuable insights into optimizing financial strategies for enhancing the effectiveness of climate adaptation efforts in urban transportation systems.

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# 1. Introduction

Climate change poses an increasingly urgent challenge to urban areas worldwide, necessitating swift adaptation measures to mitigate its impacts (Rezvani et al. [2023]). Among these measures, urban transportation infrastructure stands as a critical focal point, both vulnerable to the effects of climate change and a significant contributor to environmental pollution, particularly air pollution (Guo et al. [2020]). In recent times, Barcelona, like many cities worldwide, has been grappling with the escalating impacts of climate change on its urban infrastructure, particularly in the domain of transportation (Evans et al. [2020]). According to Evans et al. [2020], factors like the urban heat island effect, pluvial flooding, and rising sea levels have become pressing issues affecting the city's ability to maintain a resilient and sustainable transport system. However, while the need for adaptation is evident, the financing of such initiatives presents a formidable hurdle, often deemed financially uncertain (Knight et al. [2022]). This conundrum underscores the pressing necessity for comprehensive research into the intersection of financial mechanisms and the acceleration of urban transportation adaptation to climate change.

The motivation for this research stems from the escalating consequences of climate change on urban environments, coupled with the imperative to accelerate climate adaptation projects. Not only must the solutions be sustainable and achieve climate goals, but they also need to be implemented with urgency. This thesis studies the relationship between the acceleration of projects and a common barrier: financing. As urban centers grapple with the dual challenges of climate change and transportation emissions (Faghri [2023]), understanding the role of financial models in facilitating adaptation becomes paramount. Notably, while the impacts of climate change manifest in various forms, the focus on urban transportation acknowledges its centrality to both climate resilience and environmental sustainability. For instance, 2 of the 26 stations of the Metro Line 3 in Barcelona are already at risk of flooding with respect to current rainfall conditions, while 11 from 26 stations are at risk of flooding in future rainfall conditions (Forero-Ortiz et al. [2020]). On the one hand, Perez et al. [2008] pointed out on air pollution risk. Namely, they found that air quality in Barcelona is so poor that 3500 lives could be saved annually by reducing current levels of air pollution to meet WHO standards (Pujol and Parés [2017]). This thesis will mainly focus on urban transportation systems as a source of air pollution in cities rather than consequences of climate change on the system itself.

Despite the urgent need to mitigate the adverse effects of climate change on urban transportation systems, the financial sector struggles with uncertainties and risks associated with such investments (ECB [2022]). Climate change adaptation projects often require substantial upfront capital, long-term commitment, and carry significant risks related to regulatory changes, technological advancements, and market instability (Knight et al. [2022]). Furthermore, when conducting the research for this thesis, it became evident that there is a significant gap in the existing literature regarding the relationship between financial mechanisms and acceleration of urban transport adaptation to climate change. This gap in knowledge may be what creates a barrier for stakeholders to act, as they seek to understand the risks associated with various financing mechanisms. Understanding these dynamics is crucial for policymakers, investors, and stakeholders committed to fostering sustainable development and ensuring that communities are equipped to withstand the impacts of a changing climate.

The central aim of this thesis is to examine the influence of financial models on the acceleration of urban transportation adaptation to climate change, with a specific focus on two projects in Barcelona. This thesis seeks to elucidate the interplay between financial mechanisms and the pace at which adaptation initiatives are implemented, offering implications for future policy formulation and project development in similar contexts.

The primary research question driving this investigation is:

- What is the impact of different financial models on the acceleration of urban transportation adaptation to climate change?

To address this question comprehensively, several sub-questions guide the inquiry:

- What are the characteristics of financial models utilized to finance climate change adaptation in urban transportation, particularly focusing on loans, tax revenues, grants, and leasing?
- What defines the acceleration of urban transportation adaptation to climate change, both in conceptual and practical terms?
- How do selected financial models correlate with the acceleration of urban transport adaptation, as evidenced by the case study of two electrification projects concerning Barcelona's bus fleet?

This thesis is structured to provide a exploration of the relationship between financial mechanisms and the acceleration of urban transportation adaptation to climate change. The theoretical framework portrays the theoretical underpinnings of urban transportation adaptation acceleration, financial models, and their intersection. Drawing on relevant literature, it establishes a conceptual framework for understanding the dynamics at play. In the research methodology the case study approach focuses on two electrification projects in Barcelona. This section details the rationale behind project selection and elucidates the data sources employed. The findings of the thesis, derived from secondary data analysis, are presented in results section, offering insights into the observed impact of financial models on the acceleration of urban transportation adaptation. In discussion section the results are critically examined in light of the theoretical framework, providing context and interpretation. It explores the implications of the findings and their relevance for policy and practice. The final section synthesizes the key findings of the thesis, identifies research gaps, and offers recommendations for future studies, thereby contributing to the broader discourse on urban transportation adaptation and climate finance.

By synthesizing these perspectives, this thesis aims to contribute to the literature on effective financing strategies for sustainable urban mobility measures, aligning with the principles of Sustainable Urban Mobility Planning (The European Commission, [2013]). These principles account for planning in a functional city, cooperation across institutional boundaries, active citizen participation, assessment of past performance and prediction of future ones, long-term solutions, products quality and integration.

## 2. Theoretical Framework

### 2.1 The Impact of Single and Multiple Financing Sources on Project Acceleration

This research builds on the findings of Beecher [2021], who emphasizes the relationship between the diversity of financial models used in a project and its acceleration. Namely, they argued that projects accelerate faster if there are multiple sources at play. As this research focuses on the financial models underpinning the climate change adaptation of urban transportation systems, the theoretical framework hinges on integrating insights from studies emphasizing financial models relevant for financing climate change adaptation, variables defining acceleration of urban transport systems adaptation and observed relationship between the two.

To grasp the dynamics of adapting the built environment to climate change, it is essential to consider the role of finance. As highlighted by O'Brien et al. [2021], relying solely on private finance is insufficient for addressing climate change on a global scale. Hence, this section will delve into various public financial mechanisms and their significance in climate change adaptation and the implementation of nature-based solutions. In order to understand Sustainable Urban Mobility Plan by The European Commission [2013] it is necessary to identify revenue streams that support sustainable transport initiatives. Innovative projects and high-quality services often require additional initial investments, such as adapting infrastructure assets or acquiring new technologies that may not yet be cost-competitive with conventional solutions. In the face of constrained public budgets, cities may explore innovative funding and financing strategies (Werland and Rudolph [2019]). Before delving into specific financial models available, it is necessary to make a distinction between financing and funding.

Financing involves the mobilization of financial resources to cover initial investments required for infrastructure construction, vehicle procurement, works, or service provision. Sources of finance typically include public budgets or various forms of debt financing from private banks and investors, such as private equity firms and institutional investors like pension funds or insurers (Werland and Rudolph [2019]). On the one hand, funding involves securing financial resources to cover both initial and ongoing expenses throughout the lifecycle. Establishing a long-term funding model, which outlines plans for refinancing initial costs, is often a prerequisite for attracting private finance as well (Werland and Rudolph [2019]).

Therefore, in order to sustain adaptation of built environment to climate change, including urban transportation systems, it is necessary to plan both the financing and funding of projects. If either one is excluded, the threat of an unstable process and potentially adaptation failure is posed.

### 2.2 Public Financial Mechanisms Supporting Climate Change Adaptation Measures

This thesis explores funding and financing options available for sustainable urban transport initiatives. *Figure 2.1* delineates a scheme illustrating various funding and financing instruments. While the scheme encompasses a range of options, this research primarily centers on public funding mechanisms. As such, the focus will be directed towards the left side of the scheme, excluding the right leg from detailed observation.

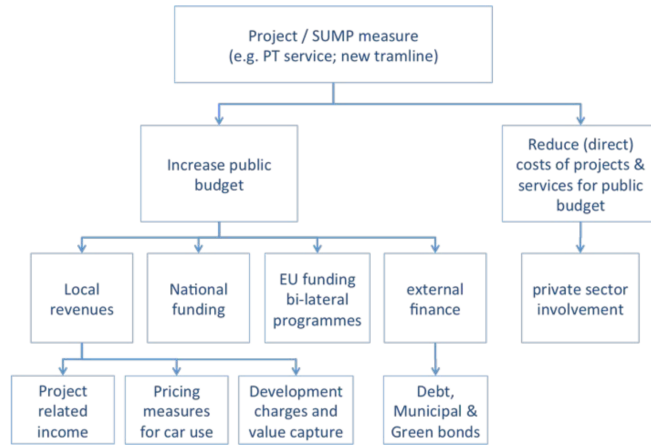


Figure 2.1: An overview of funding and financing instruments

Figure 2.1 illustrates the available mechanisms for augmenting the public budget to fund or finance various projects, such as public transport services or adaptation measures. These mechanisms are categorized into four groups: *local revenues*, *national funding*, and *EU funding bilateral programs*. In the subsequent sections, each mechanism will be examined in detail to provide a comprehensive understanding of its role and operation in supporting project financing.

### 2.2.1 Local Revenues

Typically, urban mobility systems rely heavily on funding from general city budgets and transfers from the national level (Cohen et al. [2009]). However, depending on the legal framework of the Member State and the jurisdictional powers of local administrations, municipalities may have the opportunity to leverage additional funding sources for urban mobility initiatives (Werland and Rudolph [2019]). Project-generated income, derived from sources like public transport user fares and advertising space leasing, contributes to covering operating costs for transportation solutions such as tramways. However, this income is only accessible once the service is operational (Werland and Rudolph [2019]). Therefore additional financing arrangements or private sector involvement to cover upfront construction costs is necessary. Public and private transport operators may need compensation from the general public budget or other revenue sources, such as parking management or road charges (Werland and Rudolph [2019]). Pricing measures for individual car use, such as parking fees or road tolls, aim to discourage private car usage and encourage the adoption of more sustainable transport options. However, such measures often face political resistance and require careful communication and implementation strategies to gain public acceptance (Amick [2019]).

Public capital expenditures for infrastructure and transportation services are vital for urban development (Kadyraliev et al. [2022]), especially for Transit-Oriented Development (TOD), which aims to improve public transport accessibility in new settlements. These investments often lead to increased land and real estate values near transport access points, benefiting private property owners (Mikelbank [2004]). However, new residential developments also bring more road traffic and increased demand for public transport services (UK-Government [2023]), putting pressure on existing infrastructure without the local authorities benefiting from the increased land value resulting from planning permissions. To address this, cities have introduced various mechanisms to try to capture a portion of the added value from key beneficiaries, such as property owners and land developers. Value capture mechanisms aim to link rising land and property values with the provision of public transport services (Salon and Shewmake [2011]), with approaches varying depending on the project cycle stage and the parties involved. Mobility taxes, like those levied by the Metropolitan Area of Barcelona (AMB), are based on real estate

values and invested into improving connectivity and functionality of the transport system (Werland and Rudolph [2019]).

Voluntary capture is another approach, where developers or property owners voluntarily contribute towards public infrastructure costs in exchange for anticipated benefits (Suzuki et al. [2015]). While these contributions are typically one-time payments for infrastructure construction, they do not cover long-term operational expenses.

### **2.2.2 National funding**

Financial transfers from the national budget or higher level governments to municipalities are frequently utilized to subsidize public transport services (Werland and Rudolph [2019]). For instance, The Local Sustainable Transport Fund (LSTF) was established as a funding initiative for sustainable transportation projects in England. Through competitive calls, cities had the opportunity to apply for both large and smaller project funding in forms of grants, with objectives aimed at bolstering the local economy by alleviating congestion, improving journey time reliability, and enhancing access to employment and services, and mitigating carbon emissions by promoting the transition to sustainable modes of transportation (Werland and Rudolph [2019]). Another example is provided by The German Federal Ministry of the Environment. They have initiated a fund of approximately 300 million euros to aid cities and public transport operators in procuring electric and plug-in electric buses (BMW [2018]). The program offers coverage for up to 80 percent of the additional investment costs compared to conventional diesel-fueled buses, with a reduced subsidy of 40 percent for plug-in hybrid buses. Eligible expenses include costs for charging infrastructure and other necessary measures for the integration of electric buses, such as training courses and workshop facilities.

Usually, funding programs related to mobility are launched with the aim of achieving greenhouse gas emission targets, addressing climate change adaptation, or meeting air quality standards (ConsiliumEuropa [2024]). These initiatives are commonly overseen by Ministries for the Environment.

### **2.2.3 European Funding and Financing Mechanisms**

Urban mobility is a focal point within the EU's urban agenda, an initiative launched in 2016 by EU Member States to promote collaboration in urban policy, working closely with the EU Commission, and in 2014, the European Committee of the Regions expressed its support for the urban mobility package by adopting an opinion that commended the European Commission's dedication to advancing and advocating for the concept of Sustainable Urban Mobility Plans (SUMPs). (European-Parliament [2020]). During the 2014-2020 period, financial resources for urban mobility have been earmarked from various sources, including the European Regional Development Fund (ERDF), the Cohesion Fund (CF), the Connecting Europe Facility programme (CEF), the Horizon 2020 programme (H2020), and the LIFE programme (European-Parliament [2020]). Between 2021 and 2027, the proposed regulation for the Cohesion Fund and European Regional Development Fund includes provisions for directing funds towards the advancement of sustainable multimodal urban transportation. Additionally, the Horizon Europe program is set to persist in financing research and innovation initiatives focused on vehicle design, transportation systems, and intelligent mobility solutions (European-Parliament [2020]).

In the past few years, the European Investment Bank (EIB) has provided funding options through initiatives like the European Fund for Strategic Investments (EFSI) and the Safer Transport Platform (STP) (European-Parliament [2020]). Moreover, collaborative efforts between the EIB and the European Commission have led to the establishment of various joint



programs. One such initiative is the ELENA program, designed to offer support for energy efficiency and renewable energy projects, particularly focusing on buildings and innovative urban transportation (EIB [2024]). According to EIB, majority of these funding options come in form of a loan. However, financial guarantees and projects bonds are observed as well, for instance in CEF project (Werland and Rudolph [2019]).

Loans serve as a traditional means of securing investment capital for projects related to urban mobility (Werland and Rudolph [2019]). For projects over 50 million euros, European Investment bank provides long-term investment loans (EIB [2024]). This is essential from both funding and financing perspectives, as it guarantees sustained support over extended periods. Given the European Investment Bank's requirement for loan repayment and low interest rates, along with the need for projects to align with EU policy goals, investment endeavors must demonstrate their economic, financial, technical, and environmental viability. Projects are not meant for monetary return on investments, but rather pose an expectation of added value through improved public services and sustainable adaptation to climate change (EIB [2024]). However, they are still expected to *"demonstrate a high economic rate of return, including externalities, public transport, rail, inter-modal and waterborne transport projects are accepted with lower returns compared to road projects"*, Werland and Rudolph, 2019, 26.

The last financial mechanism to be discussed is a fund. An instance of a fund is The European Fund for Strategic Investments (EFSI), and it is a collaborative effort between the European Commission and the European Investment Bank aimed at backing strategic investments across crucial sectors in Europe, including transportation (Werland and Rudolph [2019]). EFSI operates as a guarantee mechanism, enabling the financing of projects associated with elevated risks. This means that the fund provides a level of assurance to investors, encouraging their participation in projects that may involve higher levels of uncertainty or risk. By mitigating some of the financial risk involved, the EFSI facilitates the implementation of projects that might otherwise struggle to secure funding. This mechanism thus plays a crucial role in supporting the development of initiatives with the potential for significant impact but may face challenges in attracting traditional financing.

## **2.3 Acceleration of Urban Transportation Systems' Adaptation to Climate Change**

The dependent variable of this research is the acceleration of urban transportation systems' adaptation to climate change. In order to analyze the relationship between independent and dependent variable, it is crucial to elaborate on what acceleration of adaptation to climate change entails.

Adaptation involves adjusting to present or anticipated climate conditions and their impacts. In human systems, adaptation aims to mitigate harm or capitalize on advantageous opportunities. As climate change poses increasing threats, a deeper examination of transformational adaptation becomes necessary. Transformational adaptation entails altering fundamental system attributes in response to climate and its effects (Woodward et al. [2014]). Methods and strategies of measuring adaptation to climate change are diverse and complex. Craft and Fisher [2016] developed scorecards to assess institutional capacity for utilizing climate information and theories of change. These tools help explore how this capacity translates into local climate resilience and its aggregation at broader scales to foster climate-resilient development.

Given the focus of this thesis, simpler criteria is adopted to ensure manageability and clarity.

These criteria include:

- Assessing the ability of adaptation initiatives to adhere to the initially defined timeframe.
- Evaluating the extent to which these initiatives achieve the specified reduction in a particular environmental pollutant.

## 2.4 Interconnection of Financial Mechanisms and Acceleration of Urban Transportation Adaptation to Climate Change

In examining the interconnection between financial mechanisms and the acceleration of urban transportation adaptation to climate change, it is crucial to understand the relationship between these two variables. Financial mechanisms play a pivotal role in shaping the pace and effectiveness of adaptation efforts within urban transportation systems (Craft and Fisher [2016]). The availability of funding, the accessibility of financial instruments, and the efficiency of financial processes all influence the ability of urban areas to swiftly implement adaptation measures (Woodward et al. [2014]). This necessitates the individual examination of each urban area, as differences may occur due to differing contextual backgrounds.

By diversifying financial streams, projects gain access to a broader spectrum of resources and expertise, which can streamline implementation processes and improve adaptability to changing circumstances (EIB [2023]). From a logical standpoint, blending various financial models may reduce risks linked to excessive dependence on a sole source, thereby fostering resilience when facing uncertainties. Hence, both multiple and single finance sources have a direct relationship with the acceleration of projects (*Figure 2.2*). The pace of acceleration is to be measured in case study of two bus electrification projects in Barcelona. However, this thesis anticipates that projects stimulated by a mix of financial mechanisms will exhibit accelerated progress in urban transportation adaptation to climate change compared to those relying solely on funding from one financial model.

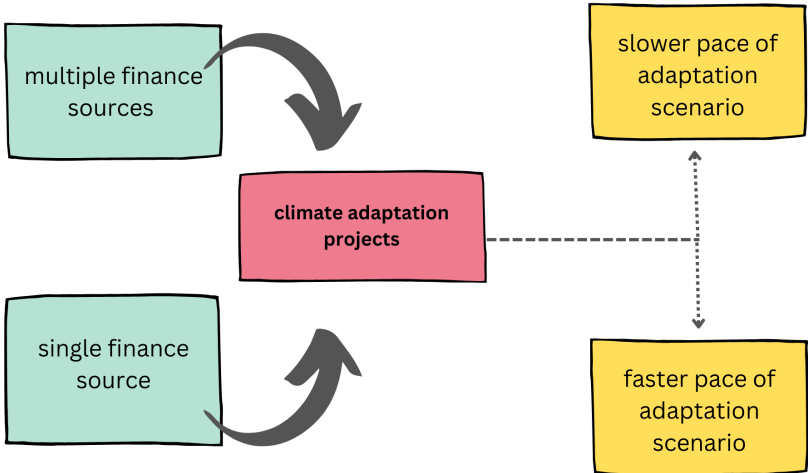


Figure 2.2: Conceptual Model employed in the thesis

## 3. Methodology

### 3.1 Data and Methods

This thesis utilizes a comparative case study methodology. GERRING [2004] posits that case studies possess both strengths and weaknesses. Nevertheless, given the preference for a place-specific approach when examining urban areas and their challenges, this methodology is deemed appropriate for this research. The two research methods chosen for data collection on the relationship between financial mechanisms and acceleration of urban transport adaptation to climate change was literature review, with a specific focus on the case study of Barcelona's urban transportation system. To collect the literature for this study, I utilized a multifaceted approach involving several databases and search engines to ensure comprehensive coverage and replicability. Firstly, I accessed the archives of the European Investment Bank (EIB) to obtain relevant financial and policy documents. Secondly, I reviewed public documents from the Barcelona government to gather localized data and policy information. Additionally, I searched for scientific articles using Google Scholar and Smart Cat to include peer-reviewed academic research. The search queries included keywords such as "European Investment Bank," "urban development policies in Barcelona," "sustainable investment," "public infrastructure projects," and "climate change adaptation." By documenting these specific sources and search queries, I ensure that the study can be replicated and the literature review process can be transparently followed.

### 3.2 The Case Study of Barcelona

Barcelona, as one of Spain's coastal cities, faces significant challenges posed by climate change, making the adaptation of its urban transportation systems imperative (Carlos [2024]). With a growing population and the associated increase in urbanization, the city is experiencing heightened pressures on its transportation infrastructure (Catalán et al. [2008]). Moreover, rising temperatures exacerbate the urban heat island effect, leading to discomfort and health risks for residents, as well as increased energy consumption for cooling systems within transportation facilities (Salvati et al. [2017]).

Additionally, the risk of increased flooding threatens the resilience of Barcelona's transportation infrastructure. Extreme weather events, such as intense rainfall and storm surges, can overwhelm drainage systems and inundate roads, railways, and other transport facilities, disrupting services and causing economic losses (Forero-Ortiz et al. [2020]).

Given these challenges, Spain's coastal cities, including Barcelona, are at the forefront of climate change impacts and are thus compelled to prioritize adaptation measures within their urban transportation systems. By investing in resilient infrastructure, implementing sustainable transportation solutions, and integrating climate adaptation into urban planning processes, Barcelona aims to enhance its capacity to withstand the risks of extreme weather events and ensure the continued functionality and accessibility of its transportation networks (Albalade et al. [2010]). The choice of Barcelona as a case city to study is driven by its vulnerability to climate change and efforts made in climate change adaptation and mitigation. For instance, besides bus electrification initiatives, the implementation of 'superblocks' is leading Barcelona's urban development (Sivoris [2019]). These structures ensure walkability of neighborhoods and provide bicycle infrastructure. Additionally, 'superblocks' are expected to ensure peaceful streets since their purpose is to reduce the number of cars commuting through Barcelona and the space that cars occupy.

In order to thoroughly examine the relationship between acceleration of urban transport adaptation and financial models employed, the study will scope down to two fairly similar

projects in terms of target goal and investment product. Namely, these two initiatives focus on electrification of bus fleet in Barcelona and therefore reduce CO2 emissions which are the leading cause of air pollution (Guo et al. [2020]). Both of these projects are aligned with Barcelona's 2030 Agenda, as outlined in the Annual Monitoring Report (BCC [2022]). This agenda includes a commitment to achieving a 45 percent reduction in CO2 emissions.

These projects are relevant due to their distinct backgrounds, providing insights into the potential impact of financial mechanisms on project acceleration. While one project relied on a single funding source, the other was fueled by multiple funding streams. This relationship aligns with the theorization by (Beecher [2021]), suggesting that projects funded through multiple sources tend to accelerate more rapidly compared to those relying on a single source. This aspect of distinct financing backgrounds enhances the significance of these projects by offering valuable insights into the influence of financial mechanisms on project acceleration. The project that relied on a single funding source presents a clear example of a traditional financing model, where the project's progress and pace of implementation are contingent upon the availability and stability of that singular funding stream (Beecher [2021]). In contrast, the project fueled by multiple funding streams represents a more diversified approach to financing, wherein the project can leverage various sources of funding, potentially mitigating risks associated with over-reliance on a single source.

One of the bus electrification initiatives that will be examined in this thesis took place between January 2011 – June 2015 (EnergyCities [2022]) under name Electrobus. The Electrobus initiative was spearheaded by Barcelona's public transport authority, TMB (Transports Metropolitans de Barcelona), with the aim of transforming the city's bus fleet into hybrid vehicles and re-vamping the entire urban transportation network. It was anticipated that the implementation of ELlectrobus will result in significant energy savings totaling 61.4 GWh throughout the project's duration, along with an annual reduction of 16,400 tonnes of CO2 emissions (EnergyCities [2022]). The other analyzed project is the TB Clean Urban Transport Fleet Renewal initiative (EIB [2019]) focused on financing the electrification of buses in Barcelona, aiming to replace outdated diesel and compressed natural gas vehicles with cleaner alternatives. This initiative involved introducing 116 new electric buses, 63 hybrid buses, and 75 buses utilizing the latest compressed natural gas technology, along with replacing 20 diesel-powered double-decker tourist buses with hybrid models (EIB [2019]).

The findings of the examination of these projects will be presented and elaborated upon in the results and discussion section of this study. However, data management issues arise due to challenges encountered, including a lack of response from organizations or individuals involved in urban transportation adaptation projects in Barcelona. While interviews could have provided valuable insights, reliance on secondary data sources becomes imperative due to these challenges.

## 4. Results and Discussion

In this chapter, two bus electrification projects in Barcelona will be examined through a theoretical lens. The discussion will be structured around the sub-questions outlined in the introduction, providing insights into the background and implementation of these projects. The first subsection will present findings regarding the financial mechanisms utilized, detailing the sources of funding and investment models involved. Following this, the second subsection will focus on the acceleration of these projects, evaluating their adherence to the designated timeframe and the achievement of initial objectives. Lastly, the interplay between financial mechanisms and project acceleration will be analyzed, assessing whether the hypothesis proposed in the introduction holds true. This discussion will provide a comprehensive understanding of the relationship between financial strategies and the pace of project implementation.

### 4.1 Utilized Financial Mechanisms in Bus Electrification projects in Barcelona

This section will present and analyze the findings of the research on the financial models employed in two selected bus electrification projects in Barcelona, in chronological order.

#### 4.1.1 Project ELECTROBUS

The Electrobus project, representing a substantial investment of 36,900,000 euros (EIB [2017]), stood as a comprehensive initiative directed towards aligning Barcelona's urban transportation system with the challenges posed by climate change. In securing the necessary financial resources, the project received support from the ELENA program, which granted approximately 1,500,000 million euros (EIB [2017]). To bridge the remaining funding gap, a combination of tax revenue, grants, and leasing arrangements was utilized, demonstrating a concerted effort to mobilize resources from various sources (EIB [2017]).

Despite its ambitious scope and vision, the Electrobus project encountered several challenges throughout its implementation journey, underscoring the need for adaptability and strategic recalibration in response to evolving circumstances (EIB [2017]). Initially conceived as a multifaceted initiative aimed at enhancing Barcelona's urban transportation system's resilience to climate change, the project's trajectory was significantly influenced by external financial conditions and logistical complexities. One notable hurdle arose from the cancellation of the planned retrofitting program, which was initially intended to transition existing diesel and compressed natural gas (CNG) buses into hybrid variants (EIB [2017]). The decision to shift towards procuring new hybrid buses was primarily driven by the realization that retrofitting existing buses to reduce environmental impact was more cost-prohibitive than acquiring new hybrid models outright. This unforeseen development prompted project leaders to swiftly reassess their strategy, leading to a strategic pivot towards the procurement of hybrid buses as a viable alternative. This strategic adjustment necessitated resource reallocation to ensure the project's continued momentum and the realization of Barcelona's overarching objectives for adaptation of urban transportation systems to climate change (EIB [2017]).

The Electrobus project aligns with the theoretical framework proposed by Beecher [2021], which emphasizes the importance of projects having a diverse range of financing sources. The financial instruments utilized in the project included a grant from the European Investment Bank (EIB) through the ELENA program, totaling EUR 1,474,502. The overall cost of the project during the implementation phase amounted to EUR 36,900,000 (EIB [2017]). Therefore, this grant accounted

for approximately 4 percent of the total project costs during the implementation phase. As time elapsed, project costs increased, inevitably leading to a decrease in the percentage of financing covered by the ELENA grant (EIB [2017]). The other 96 percent of costs were covered by Municipality of Barcelona and TMB (*Transports Metropolitans de Barcelona*) and they included a mix of tax revenue, grants and leasing (EIB [2017]). Overall, this project tapped into four separate funding sources, theoretically expected to have a positive impact on project completion.

#### **4.1.2 TB Clean Urban Transport Fleet Renewal in Barcelona**

The European Investment Bank (EIB) facilitated the upgrade of Barcelona’s urban bus fleet by providing a loan of EUR 73.5 million to TMB. The agreement, signed in Barcelona, involved EIB’s head of public sector operations in Spain, Joan Basora, and TMB’s Chief Executive Officer, Enric Cañas (EIB [2019]). This loan constituted a component of the larger initiative known as the TB Clean Urban Transport Fleet Renewal, falling under the umbrella of the Clean Urban Transport Programme Loan Spain (EIB [2019]). This comprehensive initiative entails two primary objectives: the comprehensive renewal of Barcelona’s urban public bus transport fleet from 2018 to 2021, incorporating a diverse range of vehicles powered by natural gas, hybrid diesel/electric, and electricity; and the development of essential infrastructure, including on-board IT systems and electric charging stations, to support the modernization efforts. (EIB [2019]). The project was launched on April 11, 2019, and formally executed on May 27, 2019. The European Investment Bank (EIB) provided a substantial loan totaling EUR 124 million for the entire program, which encompassed various initiatives amounting to EUR 147 million in total costs (EIB [2019]). This translates to approximately 84.35 percent coverage by the EIB finance. Specifically focusing on the bus electrification component, the project was supported by a EUR 73.5 million loan, which fully financed the procurement of 116 new electric buses, 63 hybrid models, and 75 vehicles utilizing the latest compressed natural gas technology. Additionally, the initiative facilitated the replacement of Barcelona’s 20 diesel-powered double-decker tourist buses with hybrid counterparts (EIB [2019]).

The EUR 73.5 million loan provided by the European Investment Bank (EIB) is consistent with the theoretical framework outlined by Beecher [2021], offering a contrasting perspective to the Electrobus project. This loan signifies a project reliant on a singular funding source, which, according to the theory, may experience slower acceleration in comparison to projects backed by multiple funding streams or may face challenges in completion. In summary, relying on a single funding source for this project is theoretically anticipated to adversely affect its completion.

## **4.2 Acceleration of Bus Electrification projects in Barcelona**

This section will present and analyze the findings of the research on the acceleration of the two selected bus electrification projects in Barcelona, in chronological order.

### **4.2.1 Acceleration of project ELECTROBUS**

The Electrobus project, originally slated to run from 2011 to 2015, experienced a delay in completion, ultimately finishing in 2017, two years behind schedule (EIB [2017]).

Despite this setback, the program successfully achieved its intended goals, including substantial energy savings totaling 61.4 GWh over the project’s duration and an annual reduction of 16,400 tonnes of CO<sub>2</sub> emissions (EnergyCities [2022]). The retrofitting of the bus fleet led to significant reductions in greenhouse gas emissions and energy consumption, with a remarkable 26 percent average reduction observed in GHG emissions and energy savings by the year 2014 (EnergyCities [2022]). This outcome aligns with the projections outlined in the ELENA application. Furthermore, progress was made in deploying the new orthogonal network, with 13 out of the 28 lines already operational in the metropolitan area (EnergyCities [2022]).

Returning to the theoretical framework and the two factors used to measure acceleration, it is

evident that the Electrobus project experienced a delay of two years in adhering to the initially defined timeframe for adaptation initiatives. The delay in the implementation of the Electrobus project can be attributed to several factors. Firstly, as a public transport authority, TMB is bound by strict financial regulations, requiring 50 percent of its budget to be generated from ticket sales, with the remaining 50 percent subsidized by public authorities such as the city council or regional and national government bodies, like the *Instituto para la Diversificación y el Ahorro de la Energía* (EnergyCities [2022]). Moreover, the economic crisis in Spain has created challenges for public authorities in accessing financing, further complicating matters for TMB (EnergyCities [2022]). Unable to secure loans for investment purposes, TMB faced difficulties in funding the Electrobus project. Consequently, the organization had to rely on generating cash from its budget, resulting in delays in project delivery. In terms of the other factor, achieving the specified reduction in a particular environmental pollutant, the initiatives performed admirably, successfully meeting goals of CO<sub>2</sub> reduction.

#### **4.2.2 Acceleration of TB Clean Urban Transport Fleet Renewal in Barcelona**

The TB Clean Urban Transport Fleet Renewal project, signed in 2019, successfully delivered all 116 new electric buses, 63 hybrid buses, and 75 buses utilizing the latest generation compressed natural gas technology. These vehicles were provided and put into operation by 2021 (EIB [2019]). It was fully completed within predicted timeframe. In terms of greenhouse gas emissions, while there has been a noted reduction in emissions within the transport sector, exact numerical data to quantify this reduction was not available, as noted by BCC (2022). In addition to its climate change mitigation efforts, the project also contributed to employment generation, providing approximately 1,000 jobs during the construction phase of the new vehicles (EIB [2019]). Although specific data on the exact reduction in CO<sub>2</sub> levels is unavailable, the project demonstrated positive outcomes in both factors used for the acceleration analysis. It was successfully completed within the predefined timeframe and resulted in a reduction in CO<sub>2</sub> emissions.

### **4.3 Relationship between Utilized Financial Mechanisms and Acceleration of Bus Electrification Projects in Barcelona**

The relationship between the financial mechanisms utilized and the acceleration of bus electrification projects in Barcelona presents an intriguing contrast to the theoretical expectations. While Beecher [2021] suggests that projects funded through multiple sources should progress more efficiently than those relying on a single source, this research findings diverge from this notion. In the case of the TB Clean Urban Transport Fleet Renewal project, which secured a substantial loan from the European Investment Bank, the singular large amount loan seemed to drive more efficient progress in bus electrification compared to the Electrobus project. Despite the Electrobus project benefiting from a smaller grant within its total project costs, it faced complications stemming from TMB's adherence to strict financial regulations and the broader economic crisis in Spain (EnergyCities [2022]). These challenges likely impeded the project's pace and contributed to its delay. However, both projects achieved positive outcomes in terms of reducing environmental greenhouse gas emissions. The Electrobus project, with its more extensive dataset, demonstrated clear success in meeting its emission reduction goals, while the TB Clean Urban Transport Fleet Renewal project showed a general reduction in emissions without specific numerical data. Additionally, differences in the scale and scope of bus electrification or replacement initiatives between the two projects demand consideration. The TB Clean Urban Transport Fleet Renewal project facilitated the introduction of 116 new electric buses, 63 hybrids, and 75 buses utilizing the latest compressed natural gas technology, along with the replacement of Barcelona's 20 diesel-powered double-decker tourist buses with hybrids (EIB [2019]). In contrast, the Electrobus project experienced a shift in focus due to external financial conditions, resulting in the cancellation of its retrofitting program and the procurement of 73 hybrid buses instead (EIB [2017]). This disparity in outcomes underscores the importance

of project scale and scope in determining the efficacy of financial mechanisms in accelerating urban transportation adaptation efforts.

The divergence between the thesis's primary claim that multiple financial sources facilitate faster climate adaptation project acceleration compared to a single financial source and the research results may be attributed to the individuality of each urban settlement. This suggests that the variability in project outcomes could stem from the distinct contextual factors inherent to each urban area, impacting the effectiveness of financial strategies differently. However, these findings are not intended to establish a definitive concept of this relationship but rather to illustrate its nature within the context of urban transport adaptation in Barcelona.



## 5. Conclusion

This research has explored the relationship between financial mechanisms and the acceleration of bus electrification projects in Barcelona. It revealed intriguing differences between theoretical expectations and empirical realities, challenging the view of Beecher [2021] regarding the efficacy of multiple funding sources in driving project acceleration. The Electrobus project, despite benefiting from diverse financial mechanisms, faced significant delays that can be attributed to TMB's compliance to strict financial regulations and the economic crisis in Spain. In contrast, the TB Clean Urban Transport Fleet Renewal project, financed primarily through a single large loan, demonstrated more efficient progress in bus electrification. These findings underscore the multifaceted nature of project dynamics, emphasizing the importance of contextual factors in shaping the relationship between financial mechanisms and project outcomes. The TB Clean Urban Transport Fleet Renewal was completed in its predetermined timeline, whereas the Electrobus project experienced a delay of two years. Both projects led to a reduction in greenhouse gas emissions. However, the Electrobus project provided precise numerical data, whereas the other project lacked precise information. Moreover, the TB Clean Urban Transport Fleet Renewal project created 1000 job positions, offering an additional positive impact.

Ultimately, these findings challenge the hypothesis that projects funded through multiple sources would accelerate more rapidly than those relying on a single source. The contrasting experiences of the Electrobus and TB Clean Urban Transport Fleet Renewal projects suggest that various contextual factors, including regulatory constraints, economic conditions, and project scale, play key roles in shaping the relationship between financial mechanisms and project acceleration. However, it is important to note that this research exclusively focused on the bus electrification projects in Barcelona. Consequently, a more in-depth analysis of similar metropolitan cities is crucial to determine whether Barcelona represents an outlier or if Beecher's [2021] hypothesis is unreliable when examining the relationship between financial mechanisms and urban transportation acceleration projects. Additionally, future research should explore this relationship in other urban transport adaptation projects to climate change within Barcelona.

In conclusion, this thesis contributes to the existing body of literature on urban transportation adaptation by offering insights into the complex relationship between financial mechanisms and project acceleration. By interrogating the experiences of bus electrification projects in Barcelona, this thesis illuminated the importance of considering contextual factors in shaping the effectiveness of financial interventions. Moving forward, interdisciplinary research efforts that integrate insights from finance, urban planning, and environmental studies appear to be crucial in advancing the understanding of how cities can effectively navigate the challenges of climate change and achieve sustainable urban transportation systems.

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