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The Effect of COVID-19 on the public transport system in Bogota, Colombia, and a vision for the system of the future

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ABSTRACT

The Covid-19 outbreak affected the entire world and every sector of the economy. One area that was most affected was transportation, especially public transport systems. The decrease in the ridership due to the political measures to control social distancing and the changes in the user's travel behavior has generated a greater demand for public resources to finance the operation of these systems. This thesis analyzes the challenges this situation has brought to the Integrated Public Transport System in Bogotá, D.C., Colombia, and argues that some changes are necessary to ensure its economic and operational sustainability. Qualitative methodology from semi-structured interviews with agents and stakeholders of the system was performed and assessed to understand the impacts, challenges, and strategies for the future. The analysis revealed that economic, operational, institutional, and reputational challenges were the relevant effects of the pandemic. To understand these impacts, a redesign of the structure of the system may be required; therefore, some policy and strategy recommendations were made to ensure an efficient and sustainable transport system for the post-COVID-19 period.

Keywords: Transport impacts of Covid-19, public transport systems, public subsidies, transport planning, Colombia.

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1. Introduction

1.1. Introduction

A disruptive event has unleashed an economic and social crisis affecting the entire planet as it has not been experienced before. COVID-19 was initially detected on 31 December 2019 in Wuhan City, Hubei Province, China (Priyadarshini, I et al., 2020), and on 11 March 2020, the COVID-19 have officially declared a global pandemic by the World Health Organization (WHO) (WHO, 2020). After the declaration, many countries imposed social isolation measures to control the spread of the virus. However, the COVID-19 outbreak has resulted in an incredible amount of contagion and massive death of the population worldwide (Guan L. et al., 2020). Up to now, there are more than 428 million confirmed cases and more than 6 million deaths worldwide (WHO, 2022).

Furthermore, the COVID-19 outbreak, and the preventive measures have led to a rise in global and regional inequalities and have changed many societies' social environments (Frago, L, 2021). The virus has resulted in a loss of human lives and an unprecedented disruption for multiple industries. According to Guan, L. et al. (2020), thanks to the constraint of movement measures such as quarantines, lockdowns, cancellation of public gatherings, and the closure of borders, governments aimed to reduce infection transmission by promoting social distance and reducing the mobility of people. Nevertheless, the long duration of these measures has caused immeasurable financial costs for the economy, destruction of jobs, and social instability.

The mobilization of the population and the transport infrastructure has been considered critical factors for the expansion of the virus and considering that limiting transport helps to stop the transmission of the infection (Sharifi, et al., 2020), one of the most affected sectors has been the transportation industry. As COVID-19 prevention measures have been focused on the mobility of citizenship, public transportation systems worldwide have suffered a severe depression in terms of the demand for their services and their respective revenues. For instance, in the Netherlands, during the months of March and April, following the official declaration of the pandemic, the rail public transport system reported 90% fewer passenger trips than previous months (Haas, M et al., 2020). To the same extent, in Colombia, during the mandatory quarantine period established by the government between March and August 2020, in most of the country's public transport systems,

the reduction in the demand was between 80% and 90% compared to previous months (Arellana, J et al., 2020).

Public transport systems are one of the primary mechanisms to articulate accessibility in urban populations by connecting urban structures within cities and play an essential role in increasing access to economic opportunities, reducing poverty, and improving quality of life (Guzman, L., & Oviedo, D., 2018). Unfortunately, COVID-19 has put the stability of these systems at risk by decreasing their demand, which is correlated with the depression in their income. In most cases, while revenues fell, the costs did not decrease at the same rate, creating a gap or deficit which must be covered with external resources. In this case, governments have had to inject resources to cover the debt and guarantee the operation of these systems.

In Bogotá, D.C., Colombia, one of the main characteristics of its transport structure is that fares for public transport services are designed to cover the entirety of operating costs (Hidalgo, D et al., 2013). In Colombia, during the COVID-19 outbreak, through the Decree-Law 457 of March 22, 2020, the government ordered general preventive isolation for all inhabitants of the country. This generated a challenge for the operation of the public transport system of Bogotá D.C. because its operation had to be maintained for those who could not remain in permanent isolation (TMSA, 2020). While the public transportation system in this city faced a reduction in the demand of 84% at the beginning of the pandemic and 43% at the end of the year 2020, representing a generalized reduction in the system's income, the expenses did not vary to the same extent (TMSA, 2020). Therefore, the tariff differential (income minus costs) increased, generating a requirement for more significant resources to finance the operation of the system that had to be put by the local government. According to the transportation authority (Transmilenio S.A.), in its management report for the year 2020, the tariff differential was close to COP 2,107 billion (around USD 589 million, assuming the COP/USD 3,800 exchange rate), which represented an increase of 136% compared to the differential tariff of 2019.

Considering the substantial amount of subsidy that was needed to maintain the operation of the system and the requirement of public resources in many other sectors, nowadays, there is a debate in Colombia and Bogotá D.C. among local authorities, politicians, and economists, about how to make public transport systems economically sustainable or at least how to minimize the dependence of the system on transfers from the government.

1.2. Research question

This thesis analyzes 2 main research questions. With a specific focus on Bogotá D.C., in Colombia, this research examines the impact of the COVID-19 outbreak on the public transport system. In addition, an objective of this thesis consists of providing a comprehensive understanding of the strategies that the main actors of the public transport system in Bogotá D.C. (government, regulator, and operators) are considering in the post-COVID-19 scenario, where changes in user's travel behavior, higher infrastructure demand, lower levels of users and income will be faced, to continue offering a sustainable, efficient service.

The first question is related to the impact of the pandemic on the operation and functionality of the public transport system in Bogotá D.C. about the demand and the effects of changes in user travel behavior. Therefore, the first question is:

"What are the effects of the COVID-19 outbreak on the public transport system in Bogotá D.C.?"

The second question is related to the strategies that the system requires to ensure the economic and operational sustainability of the system. This part contributes to understand how transport stakeholders can manage their needs in times of uncertainty, maintaining sustainability in operational, economic, and fiscal terms. Consequently, the second question is:

"What should be the modifications and strategies that the system could implement to ensure the economic and operational sustainability of the System?"

1.3. Theoretical relevance

Previous academic research has been done regarding the impact of the COVID-19 outbreak on the public transport system in Bogotá, D.C. However, these studies are not assessing future steps to ensure the system's efficiency and functionality based on the new reality. Likewise, these studies have not considered the ideas that different agents of the integrated public transport system (SITP) of Bogotá D.C. may have to solve the structural problems and challenges that the system faces today. Although there are not so many studies assessing the case of the SITP, doing a more comprehensive look at them, two main areas of research were identified, the general effect on the demand of the system and the impacts based on socioeconomic factors.

Arellana et al. (2020) analyzed and described some of the impacts of the pandemic on air transport, freight transport, and urban transport. In the last case, they assessed 7 different cities in Colombia.

They found the effect on the demand for transport systems and its relationship with the policies ruled by the government to control the spread of the virus. Likewise, the researchers gave some recommendations for the system's sustainability, such as subsidies to maintain the operation of the systems while avoiding crowdedness and promoting other modes of transport by allocating more street spaces for cyclists and pedestrians. In the same way, Ramirez et al. (2021) found that during the peaks of the two first waves of the pandemic, the system experienced a decrease in the demand mainly because of political decisions like travel restrictions. Another significant result was that an increase in the need for the public transport system does not have a relationship with the number of infections, implying that biosafety measures inside the buses could prevent the spread of the virus.

Regarding the impact based on socioeconomic indicators, Caicedo et al. (2021) proved that in Bogotá, D.C., poor-income people had a different behavior than middle- and high-income classes during the pandemic. While poor people had the slightest reduction in using the public transport system, they returned to the system more quickly after the lockdowns. Two reasons supported that situation. The first is the low rate of vehicle ownership among poor people and the second is that they live far from working places, making it very challenging to switch to other modes of transport such as walking or riding a bike. In contrast, middle- and high-income people have higher vehicle ownership rates and live closer to job areas, making it easier to change to other modes of transport. Likewise, Dueñas et al. (2021) analyzed the changes in mobility and the public transport system and found that informal workers travel more than formal workers. Similarly, the higher the level of poverty, the higher the usage of the public system and the mobility, and the lower the level of poverty or the higher the socioeconomic conditions, the lower the mobility and the use of the system.

Although previous research found essential effects for the short- and the long- term, in the case of Arellana et al. (2020) and Ramirez et al. (2021), they did not analyze the economic and operational stability of the system. Their advice focused on providing transportation services while reducing the risk of getting the virus rather than making the system sustainable in a post-pandemic scenario. In addition, Caicedo et al. (2021) and Dueñas et al. (2021) identified trends in terms of change in travel behavior based on income, and employment status, among other socioeconomic indicators, that will influence the future; they did not generate proposals for the authorities to face new normality based on them.

All in all, this thesis aimed to complement the previous research done through data collection and a qualitative research method by analyzing the effects of the COVID-19 pandemic and its impact on the sustainability and stability of the public transport system and the operators providing these services. Therefore, a qualitative research methodology was developed by interviewing national and local government officials, operators, bus providers, and financiers. Through a set of questions, along with the analysis of the new reality of the mass transport system, the interviewers gave their opinion about the impact of the pandemic on the system, the challenges that it brought, and possible strategies that may exist to ensure the economic and operational sustainability of these kinds of systems.

1.4. Overview of the thesis

This paper is structured as follows in Section 2, a literature review where the effect of the pandemic on public transport systems worldwide is analyzed. Section 3 describes the public transport system in Bogotá, D.C and analyzes the available data regarding the pandemic's impact on this system. In Section 4, the conceptual framework and the methodology. The main results of the interviews are illustrated in Section 5. Finally, in Sections 6, 7 and 8, the conclusions and discussion include limitations and recommendations for future studies.

2. Literature Review

This Section discusses previous research and studies that have been done about the topics explained in the research question. Given the effects of the Covid-19 outbreak, many researchers have already studied the impacts of the pandemic on the transport sector. Additionally, the pandemic increased the effects of structural problems that the system had been presenting for a long time. These problems generated inefficiencies which represented an essential cost that the government could manage. Still, with COVID-19, they have gone out of all proportions, leaving a deficit that the authorities are not able to accept and that requires an additional strategy to bring the SITP closer to more efficient and sustainable systems. Therefore, some of these impacts will be analyzed in this section.

Likewise, a general explanation of the public transport system’s structure in Bogota is done, followed by the specific effect that the pandemic had on this system.

2.1. Effect of COVID-19 on public transport systems worldwide

One of the most important reasons why a reduction in the use of mass transport systems has been generated is the fear of the spread of COVID-19. These systems necessarily involve the transport of passengers in enclosed spaces (Wilbur M et al., 2020). Tirachini & Cats (2020), based on the guidelines for public transport operators prepared by the International Association of Public Transport (UITP), summarized the main factors that contribute to generate a high-risk environment for the COVID-19 contagion in mass transportation stations and vehicles:

1. Contagion risk increases given that the level of passenger occupancy is very high.
2. Minimal or non-existent control to identify infected passengers.
3. The existence of multiple surfaces (seats, handrails, doors, and ticket machines) transfers germs easily.

To reduce the transmission of the virus, regional and national restrictions in terms of movements of goods, people, services, and good hygiene have been established as predominant strategies (Chinazzi, M et al., 2020). Mojagi et al. (2021) found a "new normal" in transport procedures, represented in restrictive measures such as self-isolation in the case of infected patients, stay-at-home activities, and steering essential duty and care.

Mogaji et al. (2022), through an analysis based in Lagos, Nigeria, found that the increase in operating costs, financial sustainability, travel needs changes and revenue loss was the significant impacts of the pandemic. In this analysis, commuters expressed their decisions to adjust their travel needs because of the pandemic. The implications of the COVID-19 outbreak, the new travel behavior, along with the new routine transport procedures are corroborated by many authors. Wilbur et al. (2020) found that in Nashville and Chattanooga, fixed-line bus ridership dropped by 66.9% and 65.1% from 2019 before stabilizing at 48,4% and 42,8% declines, respectively. Likewise, Fumagali et al. (2021) identified that before the COVID-19 pandemic, Curitiba's bus public transportation system mobilized 1,36 million passengers in a working day. In the middle of March 2020, when the social distancing measures went rigorous, the number of passengers per day was only 200 thousand per day, representing a decline of more than 80%. Gao et al. (2020) found that in New York City, average subway and commuter rail ridership was down 80%, while bus ridership was down 50% in the first week of July 2020, with a peak subway ridership decline

of 94% in late March. In addition, Arellana et al. (2020) found that in most of the Colombian public transport systems, the reduction in the demand lies between 80% and 90% compared to the previous months. Finally, Tirachini & Cats (2020), based on the Google Mobility Reports Data, identified the effect of the pandemic on many countries, as it is shown in the following graph:

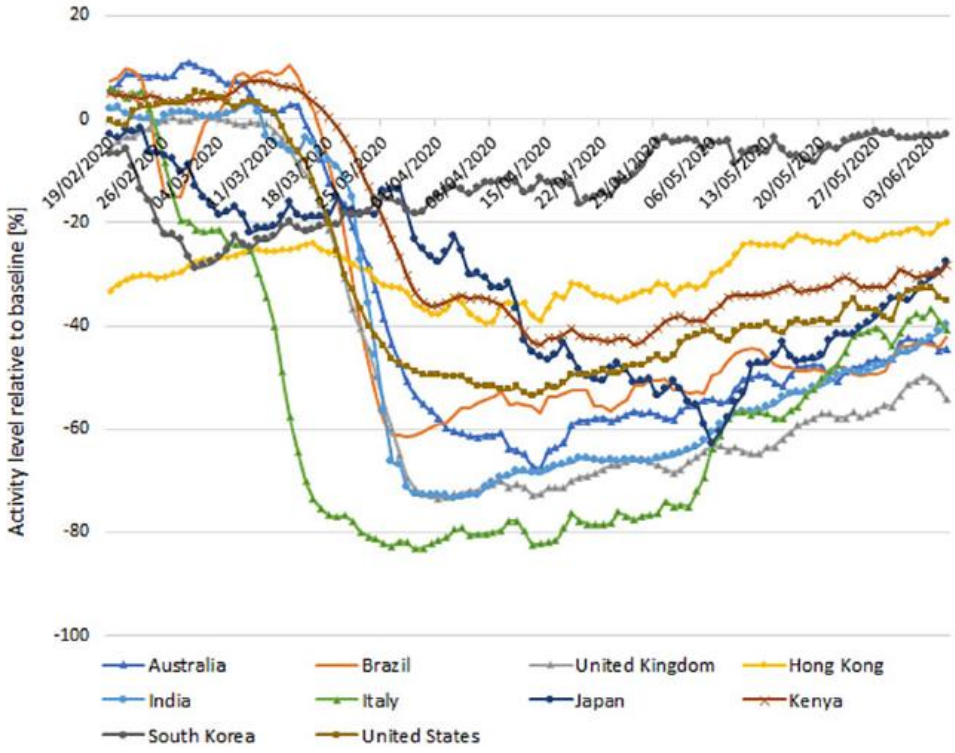

Figure 1. Effect of the pandemic on demand for public transport systems. **Note:** This figure shows the demand variation of public transportation hubs (subway, bus, and train stations); five-day moving average between February 15 and June 5, 2020. **Source:** *Tirachini & Cats, 2020, p 2.*

All in all, mass transport systems have been affected by increased costs (new hygiene and cleaning standards) and lower revenues because of lower demand. According to Fumagali et al. (2021), public transportation systems, as in Curitiba, Brazil, are still operating only because the municipality is paying the operators to have more buses during rush hours and buses almost empty on other day periods. Therefore, the only way to maintain the operation of these systems is with a more significant contribution (subsidy) of public resources. Tirachini & Cats (2020) found that several public transportation agencies are struggling financially, putting pressure on governments. For instance, the New York Metropolitan Transportation Authority (MTA) is looking for a $4 billion bailout due to the pandemic (Goldbaum 2020). In Santiago, Chile, the government plans to compensate bus operators for up to 80% of the loss in demand (DF 2020). Likewise, the Dutch

government has assigned €1.5 billion to pay the Dutch Railways (NS) and leading urban public transport operators (NOS 2020). The Colombian case is not different; the transportation authority (Transmilenio S.A.), in its management report, indicated that for the year 2020, the tariff differential was close to COP 2,107 billion (around USD 589 million, assuming the COP/USD 3,800 exchange rate), which represented an increase of 136% compared to the differential tariff of 2019.

The main problem facing the world in this situation is the possibility of bankruptcy of public transportation providers, given the decrease in demand, if they are not rescued. (Tirachini & Cats, 2020). Considering that currently, most of the economic sectors in the world continue to be impacted by the pandemic and its aftermath, it is important to analyze the strategies that must be implemented so that the operations of the systems remain sustainable in economic and operational terms.

2.2. Effect of COVID-19 on people's travel behavior regarding public transport systems

As explained previously, human interaction has been seen as an essential risk factor for spreading contagious diseases. For that reason, during the beginning of the pandemic, governments imposed some measures to control individual mobility. These policies include school closures, home-office, closure of commercial and retail shops, restrictions on public gatherings, curfews, lockdowns, and suspending public transport (Abdullah, M. et al., 2020). The side effect or the externality of these kinds of measures caused was the disruption in how people travel within a city. According to Zhao et al. (2018), "travel pattern changes" can be considered sudden and continuous modifications in the pattern of travel behavior. According to Kim et al. (2017), one of the reasons how the COVID-19 affected travel behavior was the perceived risk and the fear of infection that influenced particularly public transport usage. This situation is not different from what governments and countries have faced in outbreaks of viruses other than COVID-19. Some studies found that epidemics from viruses such as Ebola, SARS, MERS and Zika Virus have caused travel reductions and changes in travel behavior (Anwari N. et al., 2021). The main difference in the impact of previous outbreaks is that they were limited to specific locations or geographic areas, while COVID-19 affected the entire world (Anwari, N. et al., 2021).

Previous studies emphasize how people's travel behaviors varied considerably during the pandemic. These changes vary according to many factors, including demographic characteristics

(mainly age and income) and people's attitudes regarding the risk of contagion (Abdullah M. et al., 2020). Reviewing specific cases, it was found that in a study conducted in Hong Kong during the beginning of the pandemic, 40% of the people surveyed answered that they would not use the public transport system (Kwok et al., 2020). Likewise, Bucsky (2020) found that in Budapest, Hungary, the demand for the public transport system was reduced by 80%, while private vehicle use increased from 43% to 65%. Regarding qualitative studies, Yıldırım et al. (2020), through a study carried out in Turkey, concluded that one of the most important measures taken by citizens was the avoidance of public transportation. In the same way, De Vos (2020) states that social distancing will be part of the world after the pandemic and that due to COVID-19, people will reduce their trips and prefer the use of active modes or cars over public transport.

Teleworking, e-commerce, entertainment media, social and internet media communication, and the prevalence of personal mobility (Shamshiripour et al., 2020) are new trends that explain the change in people's travel behavior. The existing research predicts that the frequency and the reason for being out of home will change significantly because of the whole situation with the pandemic (De Vos, 2020). De Haas et al., 2020, conducted a study in the Netherlands and found that 80% of the people reduced their activities outside their home, 44% of workers started working in a home-office scheme, and 30% of these workers attended more online meetings. In addition, the frequency of trips was reduced by 55%, and the distance traveled dropped by 68%. Regarding shopping, Zhang et al., 2021, found that in Hong Kong, during the first year of the pandemic, trips to shopping and amusement areas declined by 42% and 82%, respectively.

Many studies done to research this topic have been conducted in advanced countries, while few studies have been done in developing countries (Anwari, N. et al., 2021). Therefore, studies in both countries were analyzed to find their main trends. N. Anwari et al. (2021) performed research in Bangladesh and compared changes in travel behavior before and during the pandemic. Analyzing trip purposes, they found that before the COVID-19 outbreak, people would visit shops 13 – 24 times per month, while during the pandemic, the number of times visiting shops was less than 5 times. In the same way, online shopping increased by 164%, and online work increased by 953%. Analyzing travel mode choice, they found that 25% and 21,33% of the people who used the public system before the pandemic shifted their preferences to private vehicles and Non-Motorised Vehicles (NMVs) during a pandemic. In general, this study highlighted several implications for transport planning and policy making because of the reduction of 55% in the usage

of the public system and the shift in the preferences of transport which migrated to private cars and NMVs.

Shamshiripour et al. (2020) practiced a survey in Chicago, USA, to find attitude and behavior changes caused by the pandemic. First, 48% of the respondents started working from home during the outbreak, while just 15% worked remotely. Second, there was a 550% growth in the proportion of online grocery shoppers and 150% growth in the users of online delivery platforms for ordering food. Third, regarding the perceived risk of traveling towards different modes of transport, they found that private cars, private bikes, and walking have the lowest risk perception (86%, 71% and 77%, respectively). On the contrary, public transport, taxi and the pooled ride had the highest risk perception (78%, 59% and 72%, respectively). Likewise, in a similar study done in Indonesia, Zudhy et al. (2022) found that during the pandemic, the respondents reduced their average work/school trips from 5 times per week to 2. Regarding dine-in and sightseeing trips, these declined 3 times a week. In addition, 80% declared that they changed their working conditions to teleworking, and the vast majority stopped using ride-hailing and car-based transport.

Finally, Abdullah et al. (2020) performed a relevant and massive quantitative analysis in which they explored the effects of the pandemic on travel behavior in several countries in South and South-East Asia, Oceania, the Middle East, Europe, and North America. According to their results, 56,6% of the respondents never went to the office or school during the pandemic, while just 11,4% did not feel any change because of the virus. As presented in Figure 2, traveling purposes like working, studying, and shopping was highly affected due to COVID-19. While 58% and 29% of the respondents traveled to work and review before the pandemic, just 30% and 13% traveled for these reasons, respectively. On the contrary, shopping was an activity that faced a dramatic increase in traveling during this period. Only 4% of the respondents declared traveling for shopping before the pandemic, and during it, 44% did it for this reason.

Regarding the mode of transport used for outdoor trips, the usage of the private car, walking, motorcycle, and no traveling grew during the outbreak. As opposite, public transport users decreased. Whereas using a personal vehicle, walking, motorcycle, and no traveling increased by 12%, 7%, 1% and 7%, respectively, public transport usage declined by 23%. In general, public transport was the mode that was most affected by the surge of the virus.

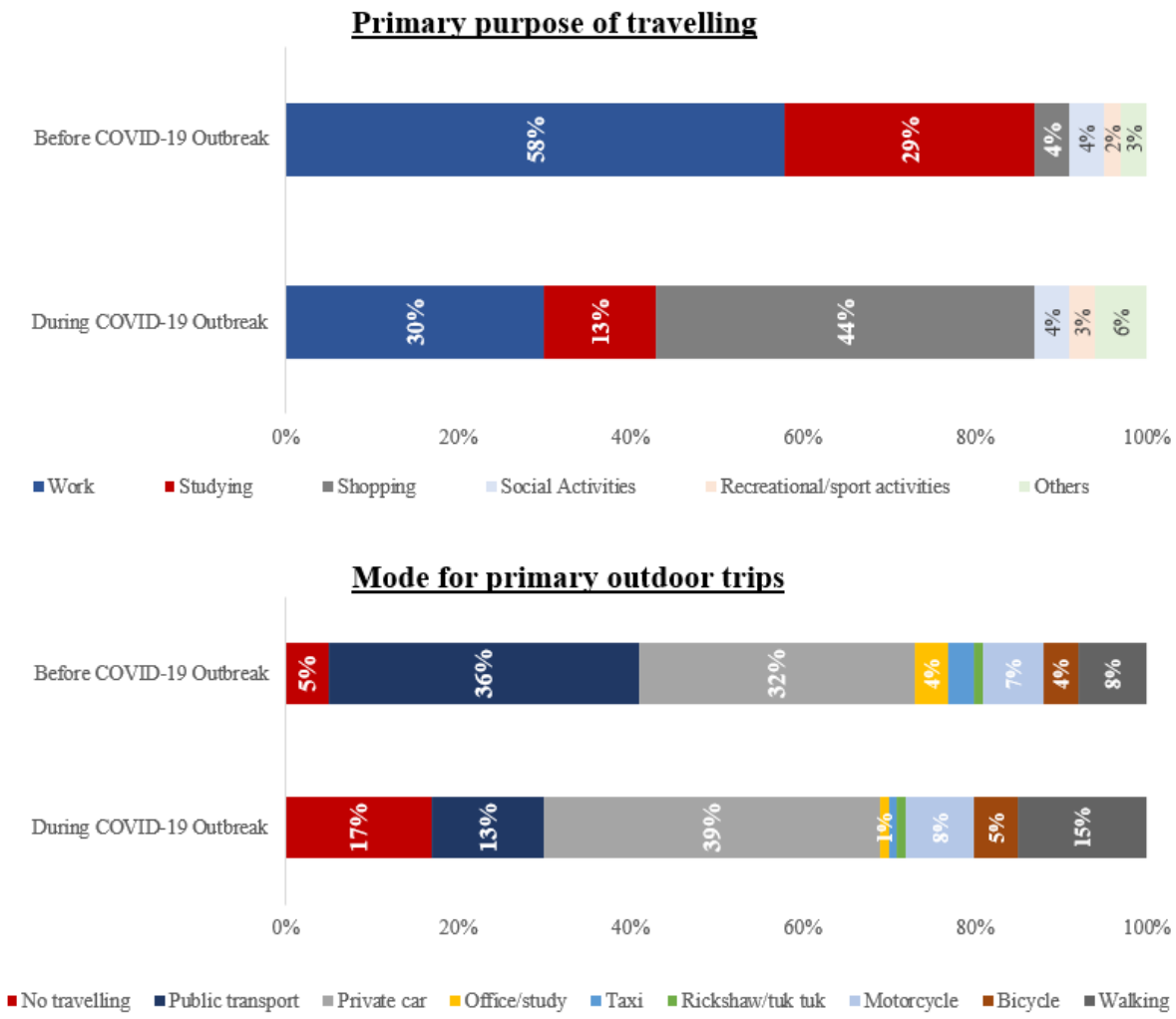

Figure 2. Main results for traveling and mode of transport. **Source:** *Abdullah et al, 2020, p 5-7.*

In addition, Abdullah et al. (2020) found some factors that affected the decision to choose a transport mode. While before the pandemic, 47% of the respondents considered safety and security as a high priority, during the pandemic, it increased to 66%. Likewise, the infection concern passed from 27% to 71% as a high priority. Furthermore, the social distance and people using facemasks were critical in this period. 71% and 60% of the respondents stated that social distancing and using facemasks are a high priority, while before the pandemic, it was 15% for both factors. Conditions such as comfort, cost and personal social status did not have a relevant variation before and during the COVID-19 outbreak.

Figure 3. Distribution of factors affecting the mode of transport. **Source:** *Abdullah et al, 2020, p 9.*

All in all, by understanding the changes and paradigms that this new everyday world has brought, and travel needs and behaviors, policymakers can get essential and insightful knowledge that may help them to redefine, plan and to make decisions during the post-pandemic reality, and thus, ensure stabilization of the transport systems to the new dynamics of the users.

2.3. Public transport system's structural factors

Worldwide, metropolitan areas have experienced a dramatical expansion bringing several problems for cities, such as unequal spatial urban development that increased the costs of providing public urban infrastructure (Sampaio B, et al., 2008). Most of the public transport systems in these highly populated areas offer a terrible service with lower frequency and quality, and high costs, mainly because of more considerable distances, unorganized urban expansion, and inefficient transport systems (Sampaio, B et al, 2008). To analyze the quality, efficiency, and sustainability of a public transport system, Santos, B (2000) made a list of characteristics to assess their performance:

i. Accessibility
ii. Travel time
iii. Trustworthiness
iv. Frequency
v. Vehicle capacity & Characteristics
vi. Route planning

Bogotá, D.C., as a megacity, had several structural problems in economic, institutional, operational, and reputational aspects before the pandemic, making the system to be conceived by the users as highly inefficient and not financially sustainable. According to the survey "*Bogota Como Vamos 2019*", users' satisfaction with the BRT and the zonal system has been below 50% for the last 10 years.

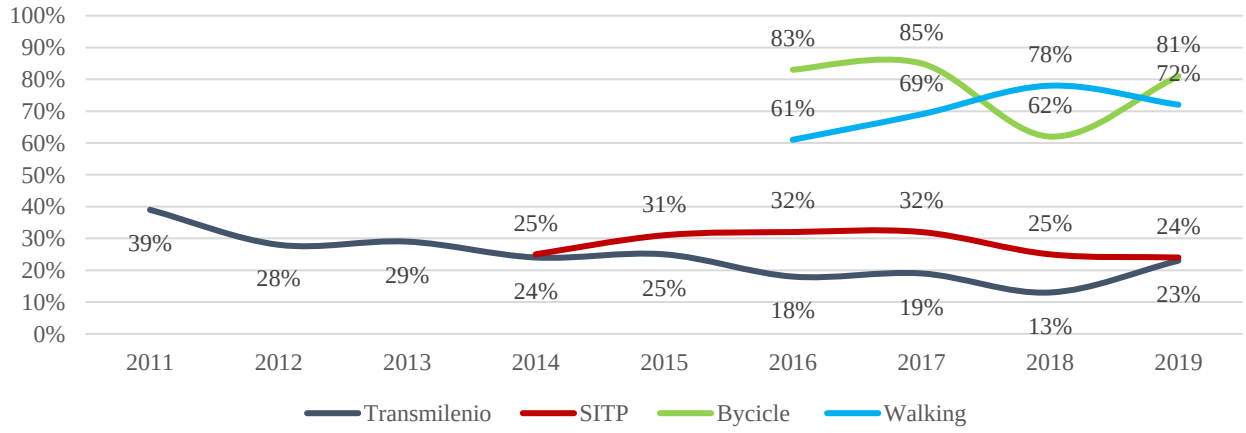

Figure 4. Satisfaction sustainable modes of transport, Bogota 2011 - 2019. **Source:** *Informe calidad de vida Bogotá D.C. (2019). Pp 157.*

Regarding efficiency indicators, users of Bogota's system have declared that excess of passengers and vehicle capacity has been the most damaging aspect, followed by perceived security within the system and the frequency of the buses (Bogota Como Vamos, 2019). After the COVID-19

outbreak, the consequences of those issues affected, even more, the demand and promoted the rise of the deficit of the system and the decrease in the users' satisfaction with the public system. According to Vickerman, 2021, a sustainable transport system in the post-COVID-19 world requires a significant rethinking to provide efficient and effective service. All new strategies and ideas had to consider the previous disruptions and issues of the system. As the aim of this thesis is to find some strategies to ensure the sustainability and efficiency of the SITP, in the following sub-chapters of this section, an explanation of the theory regarding relevant aspects of the functionality of a sustainable transport system will be explained.

2.3.1. Economic factors

In any type of business, the most important economic factor is given by income and prices. Precisely, in the case of mass transport systems, the tariff plays an essential role in their sustainability. Sampaio et al. (2008) found that inefficient systems the tariff structure can be decomposed into three alternatives: i) unitary tickets, ii) multiple trip tickets, and iii) weekly, monthly or longer periods cards for various trips. On the contrary, inefficient systems offer one or two tickets, predominantly only unitary tickets. Likewise, inefficient systems the fare price depends on the zones in which the passenger moved in a trip, the distance moved, and the length of the trip. In conclusion, Sampaio et al. (2008) believe that public transport systems should have a tariff structure that could offer different types of tickets to meet users' interests and reduce costs for passengers and transport companies.

Regarding income, public transport systems around the world faced economic issues before the pandemic. One of the most essential tools that governments have had to solve this problem is the rising tariff, however, this measure is not enough. According to Enoch, M et al., (2005), many countries have adopted earmarked taxes and charges to finance their systems and make them more efficient. For instance, in the case of France, an employer tax was included in 1971 and has helped to finance the system's expansion. In the UK, a congestion charge was introduced to maintain bus service and in the United States, car and consumption taxes are important sources to support the system's development (Enoch, M et al. 2005).

Ubbels et al. (2004) identified 2 groups of alternatives for public finance:

- The beneficiary pays – taxes for collectively pay for public goods, in the case of public transport systems, employer tax like in the case of France and property taxes.

- Polluter tax – taxes to avoid or reduce the effect of externalities. In the case of public transport systems congestion, parking on public road and car taxes.

All the previous taxes may be used to finance the public transport system besides the tariff. Nevertheless, another mechanism can add more value related to the property owner and real estate development (Enoch, M, et al. 2005). According to these authors, public transport extensions provide a positive externality to property owners and developers, which should be captured by the authorities to continue funding these projects. This process of value capture may consider property taxes and developer levies. All in all, Enoch, M et al., (2005) concludes that traditional financing methods such as tariffs are not sufficient to maintain and operate an effective and efficient transport system, and therefore it is necessary to find innovative sources that ensure the sustainability and growth of these kinds of systems.

2.3.2. Operational factors

As explained previously, efficient systems are the ones that fulfill with characteristics like accessibility, safety, and speedy, among others. According to Ibrahim (2013), an integrated transport system is the only way to meet users' requirements. The integration allows the system to operate as a unique structure for the users. In that way, the system will provide more destination options for the users (Chowdhury, S et al, 2018). Chowdhury and Ceder (2013) explained that an integrated system has five essential features: i) network integration, ii) fare integration, iii) information integration, iv) physical integration of stations, and v) coordinated schedules.

Chowdhury, S et al (2018) states that with an integrated network, the most important feature is the transfer of users between different modes of transport. These allow connections between different routes to offer a more significant number of destinations. The success of an integrated network also lies in the different modes of intermodal transport have integrated connections and synchronized transfer times in the service schedules. In addition, the stations must be physically connected to ensure transfers between the different modes, and the information on the location of each vehicle in the system must be available in real-time so that users are always informed. Finally, tariff integration is essential for an integrated transport network. According to Sharaby & Shiftan (2012), the integrated fare must meet two conditions: i) zero transfer costs and ii) all modes of transport must have the same system access and exit card. In general, an integrated multimodal system minimizes the costs. It optimizes the revenues by reducing duplication of services along

the same route and by increasing the coverage area, which, in the end will promote the usage of the system (Ibrahim, M., 2013).

Another operational factor that is relevant to the functionality of public transport systems is the organizational structure in which they operate. In the last decades, some cities have passed from public-owned and operated transport services to private operation services (Sohail, M. et al, 2006). Canitez, F. et al (2019) stated that there is an increase of public-private partnerships in the transport sector in which the public sector oversees the management and planning of the system structure and the private sector operates and offers the services. This contractual mechanism is not just applicable for the operation but also for the provision of infrastructure. There is a debate regarding which scheme (public, private or mixed) is more efficient in public transport systems. Roy, W & Billon, A, (2007) analyzed efficiency of these schemes in France. He found that in terms of technical efficiency, private outperform public operators and that public-private partnerships or semi-public schemes are the worst organizational option. Although the previous study's results are just focused on the system in France, it can give an essential overview of how these schemes can improve the efficiency of public transport systems.

A final factor to be considered is the big data that is collected in the transit system. To make the public transport system more efficient and attractive to users, it is required to do an effective plan to increase the coverage area, and the number of transfers and minimize the commuting time (Zito et al, 2011). The data provided by the user's travel behavior is essential to achieving this goal. According to Nuzzolo, A & Comi, A, (2016), information based on real-time network state can be used by travelers and planners to improve the quality of the services with services like real-time on-board load short-term forecasting, real-time best path suggestion and real-time transit assignment modeling. With those tool alternations it will be possible to reduce the time spent on the system and the costs of providing different transport modes. All in all, the evidence shows that information has become an essential tool for supporting transport operations, the performance, and the system's efficiency.

2.3.3. Institutional factors

Rahman, N., & Andullah, Y. (2016), analyzed the management structure of several transport systems around the world and gave some advice regarding the regulatory framework and the planning structure. In terms of the governance framework, the roles and responsibilities of all the

system's stakeholders must be clear. An efficient system must consider an organizational integration that ensures a clear organization of transport institutions to minimize travel times and synchronize services (Nosal, K., & Solecka, K, 2014).

According to Shibiyama, T, (2011), in every public transport system, there should be three levels of planning: strategic, tactic and operational, and two typologies of organizational structures. The first one is called "all-in-one" governmental for majority services. In this structure, the government manages all three levels of planning. In addition, one transport institution has a central role in the coordination of the activities of all public transport modes. The second one is called "vertically-separated, horizontally-integrated" service, in which the strategic and tactic levels are responsibility of the government while the private sector does the operational level. In this structure, the municipality or the transport authority works as an umbrella, coordinating the services and operations of the whole system. From both organizational structures, it is essential to highlight that the public sector activities are carried out by a single transport entity that coordinates and unites transport policy and its implementation.

Rahman, N., & Andullah, Y. (2016) believe that one of the problems public transport systems faces is the lack of a clear institutional framework. Many efficiencies can be gained by having one apparent public regional transport authority instead of having many small agencies. An integrated public transport authority has the power to control the system growth, its operation, the cooperation among public and private agents, and to develop the vision of a sustainable transport mode.

2.3.4. Reputational factors

During the pandemic, crowded places were targeted by the authorities for their ability to generate massive infections. In this way, public transport services had a reputational affectation that caused disincentives for their use and limitations to their operation. In the post-COVID-19 era, it is necessary to make some efforts to incentive people to use the public system again and to improve the reputation of these as safe places. Before the pandemic, safety was measured by two indicators: traffic accidents and crime. With the emergence of COVID-19, one more facto had to be considered: the risk of disease spread (Dong, G. et al, 2021). To increase the confidence of users on the system and to encourage them to use it again, it is necessary to increase user's satisfaction. Stradling, et al (2007), demonstrated that the higher the perceived safety by passengers, the higher the satisfaction. Dong, G. et al, (2021), gave some measures that can improve system's reputation:

monitoring public opinion related to public transport, improving public transports operation modes, and ensuring information transparency. Although safety is an important part of user's satisfaction, as it was explained previously, there are other components that are also relevant for it, such as comfort, price, and frequency, therefore, transport authorities must aim to improve the system in a general way rather than just focusing on certain factors, if the want to ensure a safety environment and to promote the usage of the system (Dong, G. et al, 2021).

2.4. Theoretical Framework

The theoretical framework for this thesis acknowledges how the changes brought by the COVID-19 outbreak and how some challenges regarding structural factors will shape a new reality for the public transport system that needs to be analyzed to ensure a sustainable operation. Therefore, the results of the literature review (impacts of COVID-19 outbreak and the economic, operational, institutional, and reputational factors), were used as basis for the interviews done.

3. Conceptualization of the System and data analysis

3.1. Characterization of Bogotá D.C and its Integrated Public Transport System (SITP)

3.1.1. Description of Bogotá D.C

Bogotá D.C is a city located in the center of the country at 2,600 meters above sea level. The importance of this city is not just for being the Capital of Colombia but also because it concentrates the political, administrative, and economic power (Chaparro, I, 2002). By 2020, Bogotá D.C and its metropolitan area accounted for 19% of the total population, representing approximately 9.6 million inhabitants (Alcaldia Bogota, 2018). Likewise, according to DANE (2022), during this year, the city's GDP represented the city's most significant share of GDP in the Colombian economy at 26%.

In terms of mobility, based on the mobility survey (2019) conducted by Bogotá's planning secretary, 13,359,728 total daily trips were made in the city, of which 37% were caused by mass public transport, 30% by bicycle and on foot, and 15% by private vehicle. In the same way, almost 50% of the trips were for study and work reasons. Regarding the modal distribution according to the household's income, the primary mode of transport used by low-income people was mass public transport (18% - 24%), while in high-income households, the direct way of transportation

was the private car (32% - 46%). Finally, Bogotá D.C is a city with a massive congestion problem, therefore, long commuting times. While a trip on the public transport system could have a commuting time of 78 minutes on average, a trip in a private car could have a commuting time of 56 minutes.

3.1.2. SITP's operational structure

The SITP comprises a network of routes distributed in three main components based on a bus system. The first is the trunk component, the central and structuring axis of the system, which serves high-demand corridors and the long-distance service by 12 exclusive halls based on a Bus Rapid Transit (BRT) system. The second is the zonal component, characterized by buses operating on mixed traffic lanes in 13 different areas of the city. Lastly, the feeder component connects peripheral zones with the trunk corridors (Guzman, L et al., 2018a).

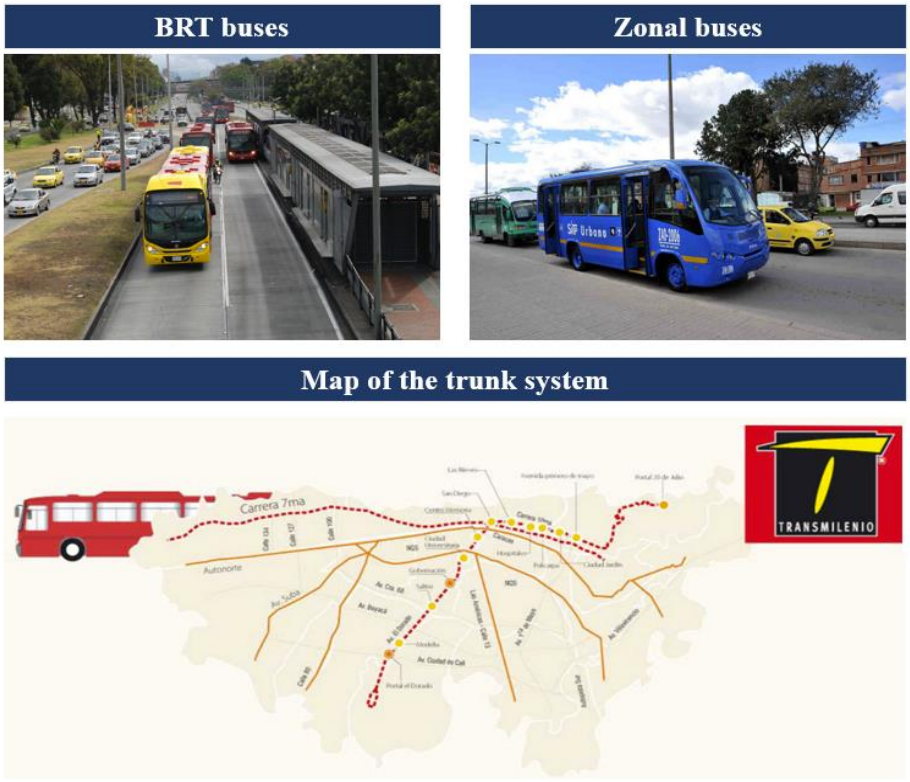

Figure 5. Trunk and zonal buses and map of the trunk system in Bogota. **Note**: This figure shows the type of bus for the trunk and the zonal components. In the same way, the map of Bogota with the trunk corridors. **Source***: Diadro (2010).*

The SITP of Bogotá D.C. operates following a hybrid model or a public-private partnership in which the public and private partners share responsibilities for the service delivery (Gilbert, A., 2008). The agents involved in the system's operation are Transmilenio S.A., IDU, Fiduciary SITP, tariff collection company, suppliers of buses and those who operate them (Medina, M., 2021), as it is presented in Figure 3. Below is a brief description of the role of each of the agents:

- The public company Transmilenio S.A. acts as the managing body that organizes the operational plan of the SITP and monitors the quality of service, guaranteeing the provision of the public transport service through concession contracts, operating contracts, and the provision of public transport infrastructure through inter-administrative agreements.
- The Urban Development Institution (IDU), a public institution, is responsible for constructing and maintaining the transport system's infrastructure through an inter-administrative agreement.
- The Fiduciary SITP is responsible for the operation of the trust that receives the income from the sales of the tickets and for making payments to the other system agents.
- Through a concession agreement, the collection company manages the system of validating the tickets and collecting the money paid by the users.
- The suppliers of buses are the agents who, through a concession agreement, are responsible for providing public transport vehicles in exchange for monthly payments for a set period.
- The operators of the buses are the agents who, through a concession agreement, operate the vehicles on the routes established by Transmilenio S.A. in exchange for monthly payments for a set period (Medina, M., 2021).

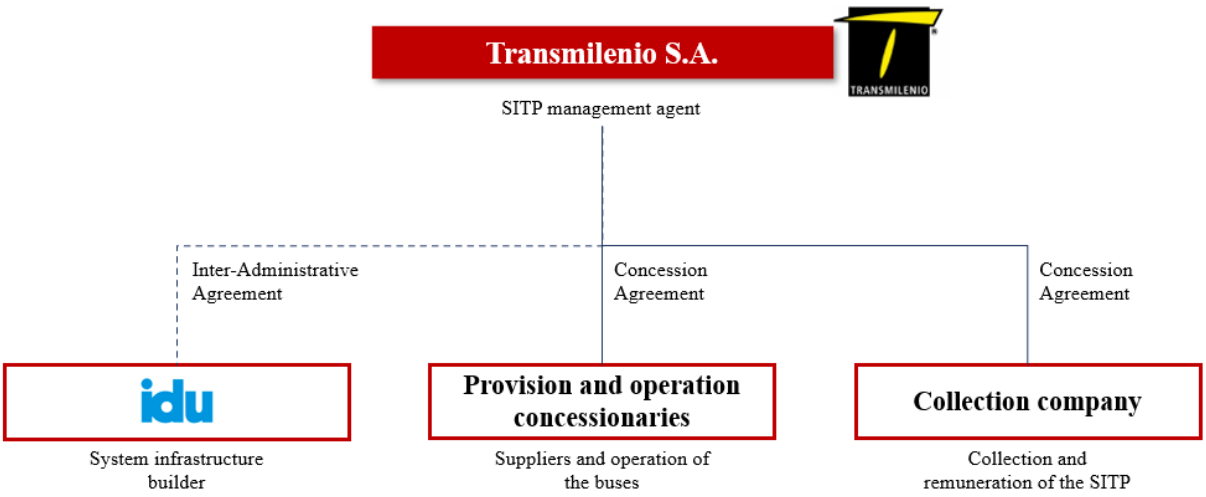

Figure 6. SITP operation system scheme. **Note**: This figure shows the agents and their role in the operation of the SITP. **Source***: TMSA (2021). Pp 18.*

3.1.3. SITP's economic structure

Regarding the economic structure of the system, it is essential to highlight some features:

- A fixed fare for the trunk and zonal components is charged to the users without considering the length of the journey. Likewise, the feeder component usage is for free.
- From its conception, the system was designed to be operationally self-sufficient with no operating subsidy from the government, meaning that all the agents of the system are supposed to cover their costs with revenues.
- While the IDU develops and maintains the system infrastructure with resources from the municipality, the costs related to the bus operation, fare collection and management, the trust agent, and the planning and management of the system should be covered by the revenues of the system.
- The system manages two types of tariffs, the technical and the user tariff. The technical tariff represents the fare needed to operate the system at an equilibrium level (cost-recovery). In contrast, the user tariff is the one charged for the system's use and is determined by the city Mayor.

  To compensate for losses or save for the profits of the system, the Tariff Stabilization Fund (FET) was created, which works as follows:

1. $If\ Technical_{Tariff} > User_{Tariff}$

$$\Rightarrow FET\ will\ compensate\ the\ tariff\ difference$$

2. $If\ Technical_{Tariff} = User_{Tariff}$

$$\Rightarrow Balanced\ in\ the\ revenues\ and\ costs\ structure$$

3. $If\ Technical_{Tariff} < User_{Tariff}$

$$\Rightarrow The\ profits\ will\ be\ transfered\ to\ the\ FET$$

In general, the FET is a fund created to manage the shortages or surpluses of resources to allow a satisfactory system operation by ensuring payment to all system agents. In periods when the user rate is higher than the technical rate, surpluses are deposited in the fund for use in future periods. On the contrary, when the user rate is lower than the technical rate, the remnants deposited in the FET will be used to meet the payments to the system agents. If there are no surpluses, the district government must contribute to the lack of resources. The risk of demand or disruptions in tariff stability will be on the public sector.

- Ridership forecast done by Transmilenio S.A. plays a vital role in determining the technical fare. If the demand exceeds the projections, there will be surpluses; on the contrary, if the demand is lower than the forecasts, there will be deficits for the system.

- Currently, the technical tariff includes other services that are not operational such as i) scrapping costs, ii) planning and supervision of the systems, and iii) infrastructure provision. In the last element, the tariff covers the purchase and provision of the buses, which are usually replaced for 10 years (the useful life of these vehicles). All in all, these kinds of costs in the technical tariff affect the financial equilibrium of the system (Gilbert, A., 2008a) (Peralta, T., & Rodriguez, C., 2016) (Diaz, R. et al., 2015) (Remolina, L, 2012).

Based on the highlights presented previously, SITP resources are managed under the following scheme:

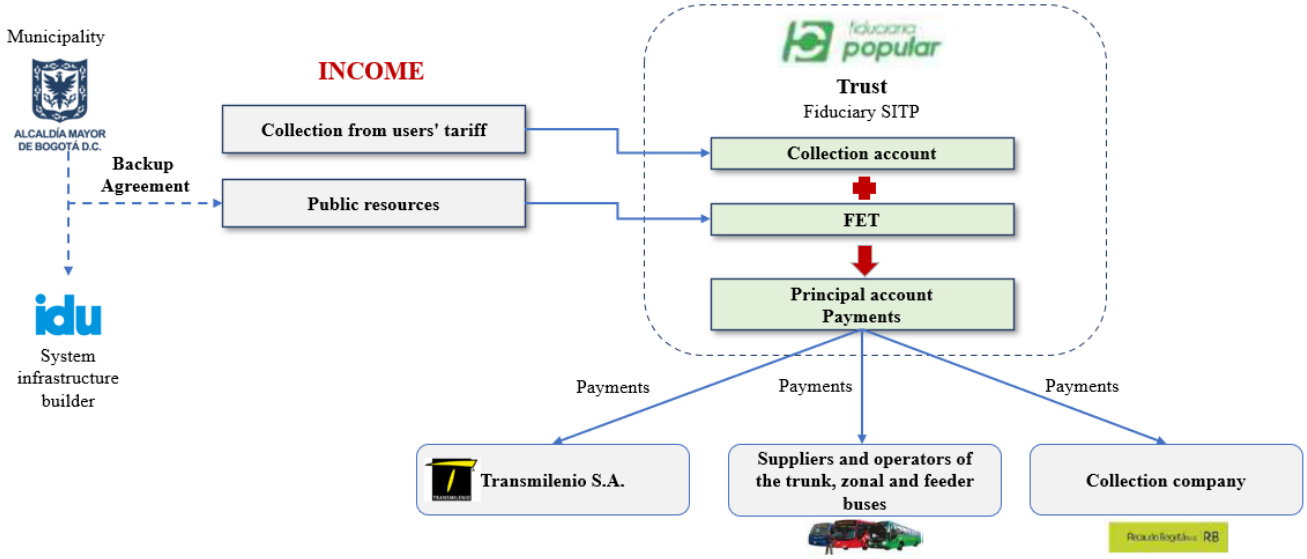

Figure 7. SITP resources cashflow. **Note:** This figure shows the operating cash flow of the income and the system's payments. **Source:** *TMSA (2021). Pp 21.*

3.2. Effect of COVID-19 on the operation and demand of the SITP

After the declaration of COVID-19 as a pandemic by the WHO, most governments worldwide took action to control the spread of the virus. The main objective of that measure was to stop the transmission by reducing the interaction between people. Although the effectiveness of these kinds of policies is not in the debate, they negatively affected many socioeconomic factors that cannot be dismissed. For instance, in Colombia, the COVID-19 outbreak affected mainly the supply and demand for air, freight and urban transport (Arellana, J et al., 2020a), both of the measures taken by the government and for fear of people of infection. Considering the situation that the society was facing due to the pandemic, the Colombian government, and the municipality of Bogotá D.C., established some of these measures as presented in Table 1.

Date	Government measure
March 6, 2020	First case of COVID-19 confirmed by the Government
March 12, 2020	State of emergency declaration
March 17, 2020	Closure of land, sea, and river borders until May 30
March 20, 2020	**Quarantine drill** in Bogota for four days

Date	Government measure
March 23, 2020	Suspension of domestic and international flights
March 25, 2020	**Mandatory quarantine** throughout the country until April 13
March 26, 2020	Measures on the provision of public transport services are imposed
April 8, 2020	**First extension of the mandatory quarantine** throughout the country until April 27
April 15, 2020	Measures to mitigate the economic effects of the pandemic in the transport sector are issued
April 24, 2020	**Second extension of the mandatory quarantine** throughout the country until May 11
May 5, 2020	**Third extension of the mandatory quarantine** throughout the country until May 25
May 22, 2020	**Fourth extension of the mandatory quarantine** throughout the country until May 31
May 28, 2020	**Fifth extension of the mandatory quarantine** throughout the country until June 30
June 17, 2020	Red alert in Bogota and closure of Transmilenio stations
July 24, 2020	Quarantine cycles by neighborhoods in Bogota
August 28, 2020	Restricted entrances to the transport system in Bogota
September 17, 2020	Official operation of the system without entry restrictions in Bogota

Table 1. Measures adopted by Colombia and Bogota's Government. **Note:** This table shows the chronology and the measures imposed to control the spread of the virus. **Source:** *Arellana, J, et al, (2020), pp 4 & TMSA, (2020), pp 65 – 66.*

Regarding the measures taken on April 15, 2020, intending to mitigate the economic effect of the pandemic in the transport sector, the national government ruled that all mass transit systems operate with a maximum capacity of 35%. Likewise, the government established a line of credit of around USD 1.3 million and a tax exemption plan to ensure the continuity of the operation provided by the public transport operators (Arellana J et al., 2020b). However, in the case of the

system of Bogotá D.C., the government of Colombia did not offer a subsidy or its resources to finance the deficit that the system was facing during that period.

In general, the main effect of the pandemic in the SITP was the decrease in users, with them the reduction of income, and the increase in costs due to the requirement from the government to ensure the service with safety protocols such as distancing between people. According to data provided by Transmilenio S.A., in March 2020 (the first month of the pandemic), the decrease in the demand and the income of the system was 35%, in April was 82%, in May 77%, and in December 37%, compared to the same month a year before. The worst month in terms of the decline in the demand was April 2020, and one year later, those indicators increased by around 164%; however, compared with the same month in 2019, the same indicators were 52% lower. By December 2021, the pandemic was still affecting the system; However, the demand and the income recovered 51% compared to December 2020; it was still 37% lower than the same month before the pandemic.

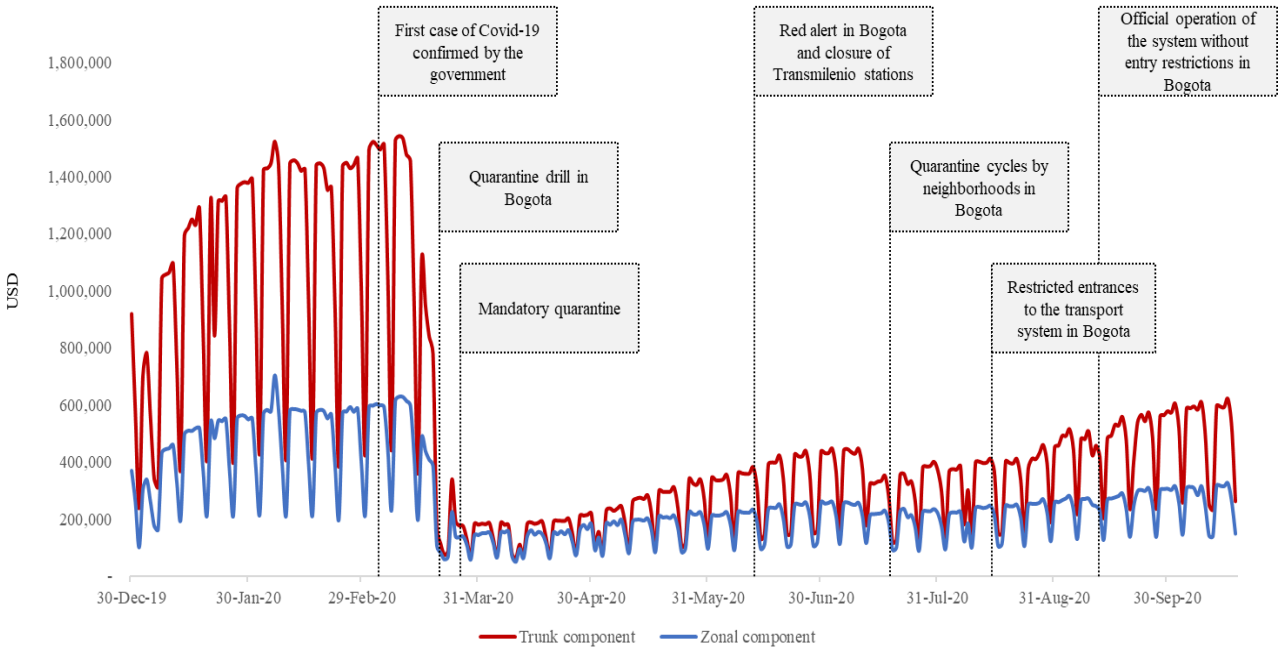

Figure 8. SITP's income during Dec-19 – Sep-20. **Note:** This figure shows the system's income broken down by trunk and zonal components between December 2019 and September 2020. The data were converted from Colombian Pesos (COP) to USD using an exchange rate of COP/USD 3.800. **Source:** *Based on the information provided by Transmilenio S.A. & TMSA, (2020), pp 66.*

As explained previously, the system's income comes mainly from the fee paid by users (users' tariff), and the costs, which are represented by the technical tariff, correspond to payments to the agents of the System. As is presented in Figure 5, the isolated measures generated a decline in the demand of more than 70%. At the same time, the costs increased (see Figure 6) because the costs were higher than the revenues ($Technical_{Tariff} > User_{Tariff}$), the district needs to provide public resources to subsidize the system through the FET. Although this situation had been presented before the pandemic (see Figure 6), due to other non-operational costs, including in the technical tariff, such as i) scrapping costs, ii) planning and supervision of the systems, and iii) infrastructure provision, it is essential to highlight that during the periods 2020 and 2021, the differential of income and expenses has generated contributions of public resources for more than USD 1,000 million, an amount that exceeds all the resources that have been contributed to the FET in past periods. In 2020 the district government had to contribute USD 527 million, and in 2021 USD 589 million; in contrast, in 2019, the contribution was around USD 213 million. It is important to note that according to TMSA (2021), in 2021, there was no increase in the user tariff, maintaining the same as those decreed in 2020, so an essential part of the tariff differential was due to this fact.

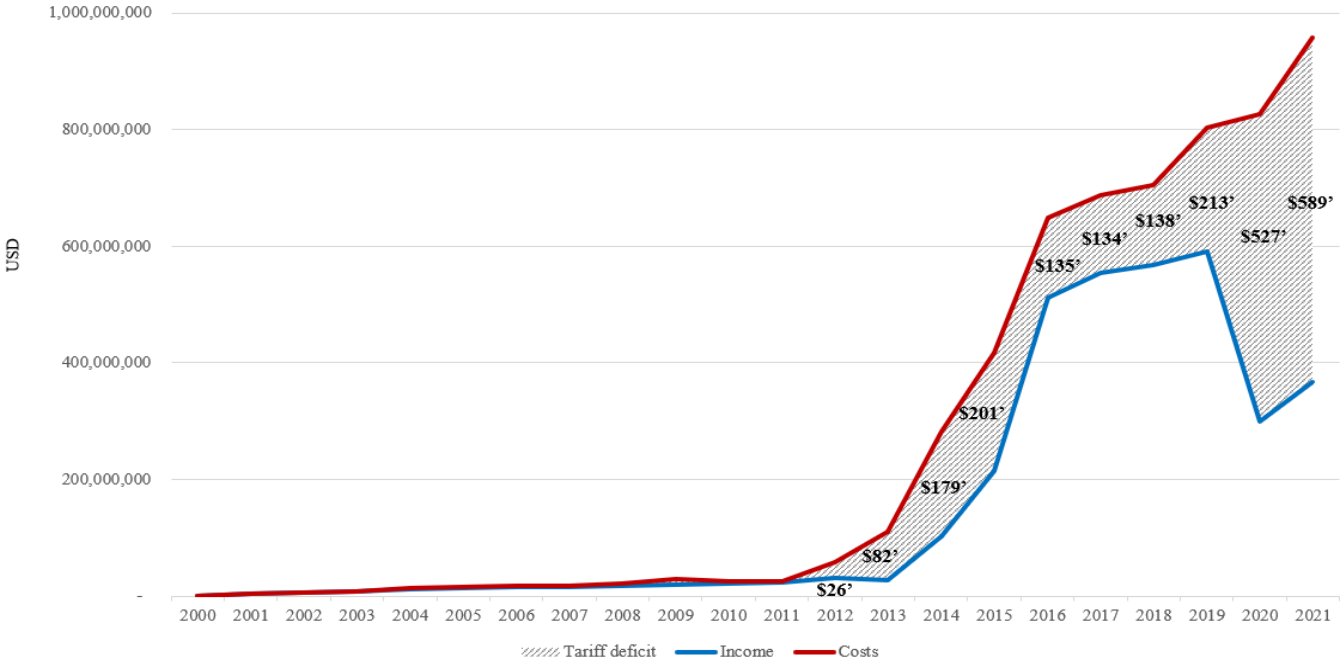

Figure 9. Income, costs, and tariff deficit 2000 – 2021. **Note:** This figure shows the performance of the income, costs, and tariff deficit between 2000 and 2021. The data were converted from Colombian

Pesos (COP) to USD using an exchange rate of COP/USD 3.800. For the tariff difference, the values are given in USD million. **Source:** *Based on the information provided by Transmilenio S.A. & TMSA, (2021), pp 193.*

All in all, the SITP is facing two main challenges. The first is related to the financial problems due to less demand and higher costs. Subsiding the system's operation is essential to guarantee its functionality; however, the COVID-19 pandemic brought many needs in different sectors that require the same attention as public transport and compete for these scarce resources. In Figure 7., is presented the contributions that the system needs in 2021. The initial budget that Transmilenio S.A. considered to subsidize the system was not enough, so in August, it was necessary to provide additional resources to meet the payments to the agents of the system. This situation represents the financial problem in which the system is found and sets off alarms in searching for solutions to modify the system's structure and obtain additional income.

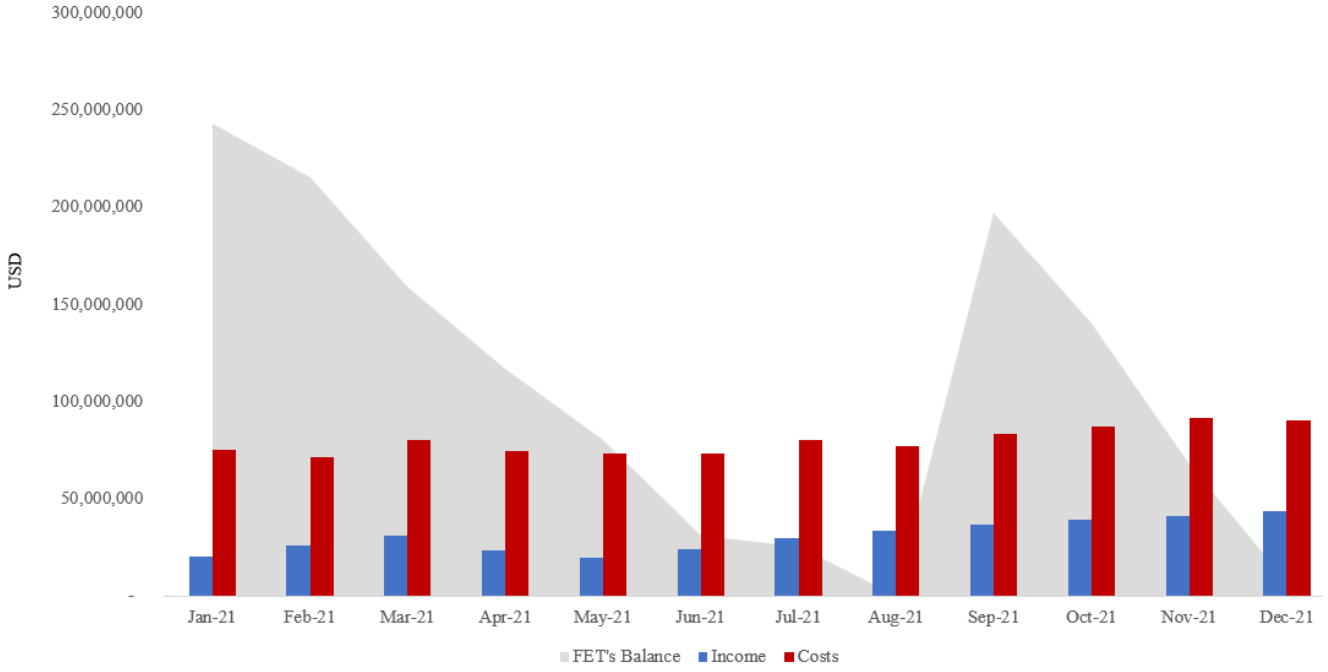

Figure 10. FET contributions performance 2021. **Note:** This figure shows the performance of the income, costs, and tariff deficit between 2000 and 2021. The data were converted from Colombian Pesos (COP) to USD using an exchange rate of COP/USD 3.800. For the tariff difference, the values are given in USD million. **Source:** *Based on the information provided by Transmilenio S.A. & TMSA, (2021), pp 194.*

Finally, the second challenge the SITP faces, which seems to be more difficult to solve, is the lower demand due to a change in users' travel behavior. Considering BRT systems operate with

higher densities, as in the case of Bogotá D.C., the spread of the virus is the primary concern that has caused some users to migrate to other transport modes (Arellana J et al., 2020). This situation reinforces the need to reform the system to adapt it to a new reality of minor users.

3.3. Effect of COVID-19 on travel behavior in Bogotá D.C

Although there are not many studies about changes in travel behavior in Colombia due to the pandemic, some surveys were analyzed to obtain some results. Moovit, a leading Mobility Service (MaaS) solutions provider and a creator of an urban mobility app, investigated trips done worldwide in 2020. Regarding Bogotá D.C., it found some insightful information about travel behavior presented in Figure 10. While more than 50% of the participants declared that because of COVID-19, they started using the public transport system less frequently, around 10% used public transportation more. In addition, nearly 20% of the respondents did not see their frequency of public transportation usage affected, and less than 10% are no longer using the public system. In general, nearly 70% of the responders saw their mobility in the public transport system affected, demonstrating the significant challenges that the system is facing.

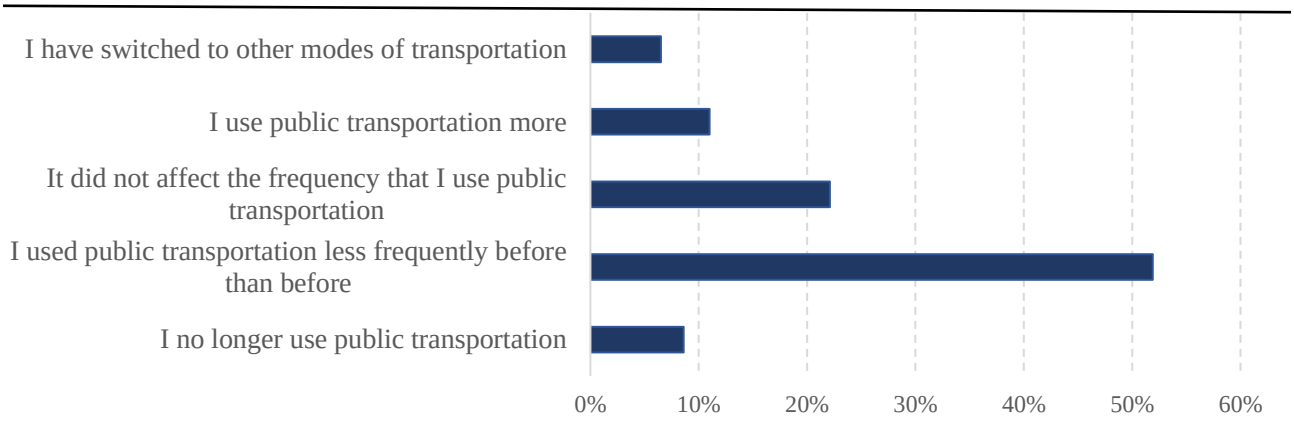

Figure 11. Frequency of public transportation usage in Bogotá D.C. **Source:** *Moovit (2022).*

About the previous results, a report on the quality of life in the city by 2020 showed the transport modal distribution before and during the pandemic, presented in Figure 11. The most affected mode of transportation was the public transport system which faced a dramatic decrease of 21%. Other methods of transport whose usage declined were private cars and motorcycles. On the contrary, walking, cycling and bus were modes of transport which increased by 3%, 5% and 14%, respectively. This report continues to show that mass public transport was the most vulnerable method due to the pandemic.

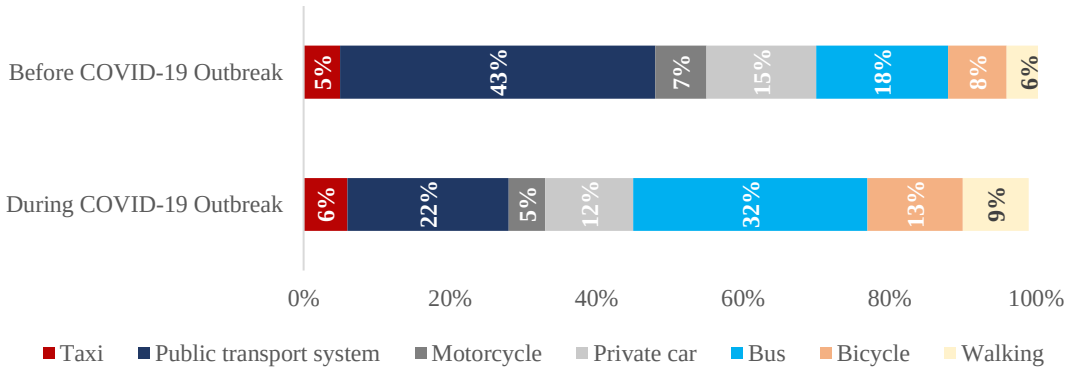

Figure 12. Modal distribution before and during the COVID-19 outbreak. **Source:** *Informe calidad de vida Bogotá D.C. (2020). Pp 238.*

Finally, Guzman et al. (2021) analyzed activity and mobility patterns in Bogotá, D.C., based on high, medium, and low income. They found that the public transport system's usage decreased among high-income and medium-income people while it increased in low-income people. Regarding private cars, medium-income people increased their usage, high-income people did not have any variation, and low-income people, their use went down. Active modes of transport like walking and cycling increased except for low-income people who did not have any alteration.

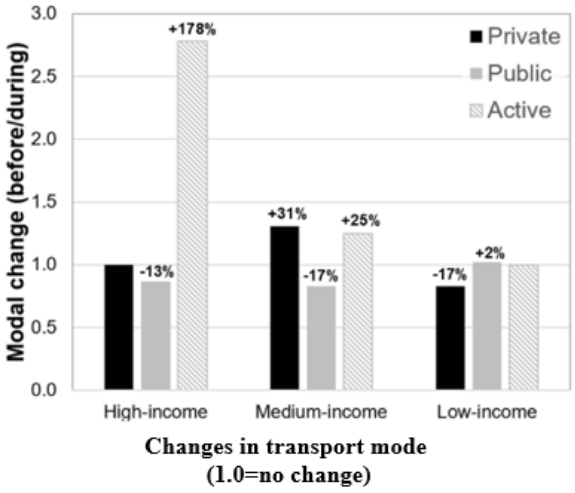

Figure 13. Changes in transport mode in Bogotá D.C. **Source:** *Guzman et al. (2021). Pp 250.*

4. Methodology

This section provides information about the qualitative research methodology used to obtain insightful data from the interviews with the stakeholders and agents of the SITP.

4.1. Methodology

4.1.1. Type of interview

Interviews are typically used to obtain data and collect information about the participants' experiences with specific research (Ryan F. et al., 2009). As Babbie explains it, E (2007) identifies three kinds of interviews: standardized, unstandardized, and semi-standardized. According to Ryan, F et al. (2009), standardized or structured interviews are based on a detailed list of questions that do not allow any deviation from the specific topic of those questions. On the contrary, unstandardized or unstructured interviews are based on open-ended questions rather than on a particular framework of questions. Between those two categories, there are semi-standardized or semi-structured interviews that follow a list of less structured questions, allowing spontaneous topics to be explored during the interview. As this research aimed to identify all the proposals, ideas, or strategies of the agents and stakeholders of the SITP to make the system economical and operationally sustainable, the methodology for the interviews chosen was the semi-standardized or semi-structured, considering that within this case, the interviewees may express their ideas instead of just answering a list of questions.

4.1.2. Interviewee sample: SITP's Agents and Stakeholders

As Mogaji E. et al. (2021) did in their analysis of the COVID-19 impacts on transportation in Lagos, Nigeria, this research adopted a purposive sampling for selecting thirteen representatives of some agents and stakeholders. The individuals were chosen considering their importance and relevance in the functionality of the public transport system.

From the perspective of the agents of the system, representatives from the following companies were chosen to conduct the interviews: Transmilenio S.A., IDU, company operators, and fleet providers. The stakeholders were selected considering their close relation with the SITP. Those stakeholders come from banking & financing, public planning, and general budget allocation. Participants working in the following companies were chosen: FDN, DNP, Municipality, Transport Ministry, and Treasury Ministry. To develop the SITP's infrastructure and its operation, financing from the public and private sectors is needed. Therefore, FDN and the Treasury Ministry were considered stakeholders. In the first case, FDN is a development bank with a mixed corporate structure (owned by the government and private sector), which has two objectives: i) financing and ii) structuring projects. FDN has worked with Transmilenio S.A. and the municipality to

structure the first metro line project and three new trunk corridors. At the same time, it is one of the financiers of the metro project. In the second case, the treasury Ministry oversees the public budget allocation from the national government. This Ministry participated in its origination for the metro project and the three new trunk corridors by committing the nation's resources to implement these projects. The two final stakeholders were the Municipality and the Transport Ministry. Their importance is related to their task in planning and leading public policies related to the development of the system, both in economic and operational terms. A summary of the agents and stakeholders selected for the interviews is presented in Figure 9.

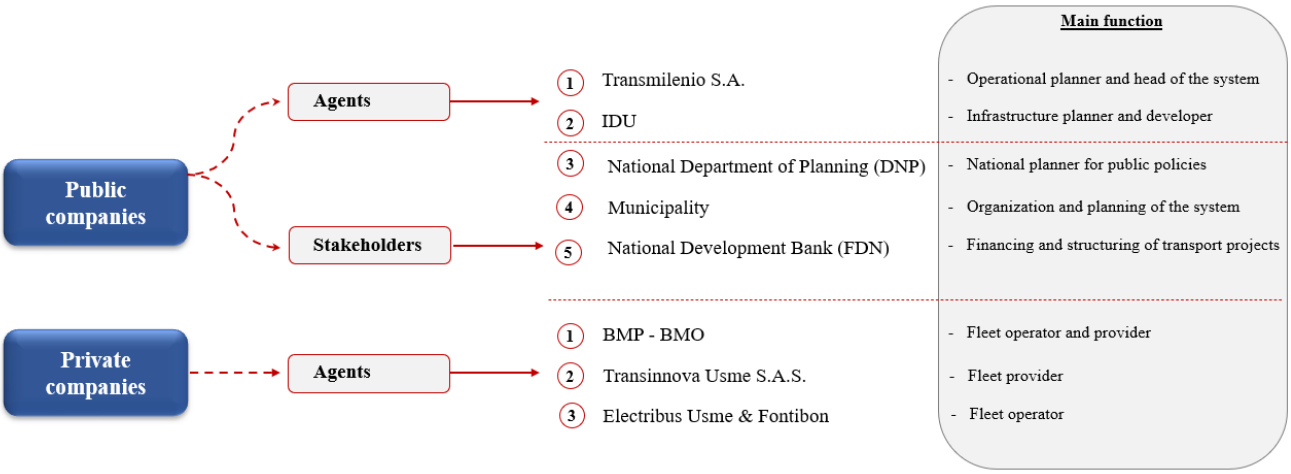

Figure 14. Agents and Stakeholders interviewed.

The interviews were done in Spanish, which is favorable for the interviewer and interviewee. All the participants came from a similar educational background, position of responsibility and age but with different years of working in the transport sector.

During the interview, the voluntary consent of all the participants was obtained. The interview was recorded, and the participants were aware of this situation. Likewise, participants accepted that all practical and personal information would be treated in confidence and that all information expressed during the interviews would be used for qualitative research. Due to geographic differences, the discussions were made and recorded on Zoom. Interviews were conducted between the 1st of June de 2022 and the 19th of June 2022, and each time varied between 30 and 60 minutes.

4.1.3. Structure of the Interview

The interviews were structured in two parts. The first part is based on the effects that COVID-19 brought to all agents and stakeholders of the system and the actions they took to react to the pandemic. In contrast, the second part refers to the challenges the system faces after the pandemic and the strategies that could be established to promote the system's sustainability and reduce its dependence on subsidies.

In appendix A, the details of the questions asked in the interviews. These questions were the structure of the interview; however, considering that all the participants represent agents and stakeholders with different roles and functions, some of the questions during the interviews could vary or be made by asking about specific topics.

5. Results

The results of the data collected from the interviews are presented in this section. All the information is organized considering the structure of the set questions (appendix A). Therefore, in the first part, the description of the impacts of the COVID-19 outbreak on agents and the system. In the second part, the strategies that the agents of the system considered for the future to ensure its sustainability.

5.1. Challenges exposed by the Covid-19 pandemic

5.1.1. Impacts and challenges to the agents' operation

In general terms, the agents of the system who were most affected in their operation were those in the public sector. In the case of bus operators and suppliers, the concession contracts considered situations such as the pandemic, allowing them to adapt to the problem without presenting significant economic effects. The operators' contracts established the payment of fixed and variable costs for the operation of the buses. The fixed costs, which included the amount of personnel, were paid by the system. However, the variable costs, which depend on the number of kilometers traveled and include gasoline, repairs, maintenance, and general expenses of the buses, decreased because Transmilenio S.A., as the managing body of the system, reduced the number of kilometers that each operating concessionaire had to operate. While the previous reduction generated a lower income level for these companies, it also reduced costs by almost a proportional amount. One of

the problems evidenced by the pandemic is that financial costs were not considered fixed costs, so, during the first months of the pandemic, some of the operating concessionaires, facing lower revenues, could not meet their financial obligations according to what was stated by the financiers. This situation was solved during the first 3 months of the pandemic. On the other hand, bus suppliers did not see their revenues affected because their contracts establish payment for bus delivery, regardless of whether they are in operation.

Transmilenio S.A., IDU and the local and national governments were highly affected from the authorities' perspective. For the local government, the most significant effect was the need to bail out the public transport system and establish all the policies to reduce the spread of the virus. Likewise, the national government had to open lines of credit for the municipalities to finance their transport systems. In fact, in 2020, the federal government will cover 50% of the system's deficit in Bogotá, D.C. In the case of Transmilenio S.A., apart from the disruption in demand and income, the biggest challenge was the operation and public policy uncertainty regarding the level of service that should be offered and the mobility restrictions. The outbreak significantly impacted the operational planning of this entity, considering that almost every day, the transport supply needed to be modified due to changes in the user's demand; however, the System's responsiveness was not as fast as it was required. According to one of the interviewees in Bogotá, D.C., modifying the fleet's routes requires at least one week, while the user's demand changes daily. Finally, IDU as an infrastructure planner had to take some measures to ensure social distancing. First, this institution invested in new infrastructure for bikes (almost new 120 kilometers) and second, it invested in the expansion of the stations of the system incorporating new transport tools due to the pandemic.

5.1.2. Impacts on the system and challenges for the upcoming years

According to all the interviewers and based on what has been presented in previous sections, the most critical impact on the system was the decreased demand and revenues, which generated pressure on public resources to finance the deficit. Nevertheless, the pandemic also brought new challenges in operational, institutional, economic, and planning matters and aggravated inefficiencies before this event. In table 2, the effects and challenges of the system are presented with their respective explanation.

Category	Impact/challenge	Description of the impact/challenge
Economic	Decreased in the revenues and increased of transport costs – Financial sustainability of the system	To ensure social distancing and contagion, the national government decided to impose certain measures to reduce human interaction. This led to restrictions on the operation of the system, for example, during the first 5 months of the pandemic, the entire fleet operated at 50% of its capacity. Likewise, as mass transport systems were identified as focus of mass contagion, users decided to stop using it or to shift to other modes of transport. Although the income decreased considerably, the costs increased by keeping the entire fleet of buses in operation and by hygiene and health measures implemented in the system. The mismatch between income and expenditure has generated a need for subsidies of more than USD 1,000 million between 2020 and 2021. All the agents of the system foresee that the deficit will continue to grow in the future due to a series of factors such as a slow recovery in demand, greater evasion in the payment of the ticket and an increase in the supply of transport of the system (3 new BRT lines, first line of the metro and commuter trains).
	Increase in evasion of payment of the ticket	Bogotá D.C., as the capital of Colombia, has a high presence of poverty and inequality. According to the interviews, the cost of transportation in the city corresponds to between 15 – 20% of the income of people with minimum wage. Due to the high cost of transportation before the pandemic the evasion in the payment of the ticket was equivalent to 18% of the income. Although there is no consensus as to the current evasion figures and there are no evasion studies with specific figures. some speak of an increase to 28%, while others speak of more than 50%. The general economic conditions of the population were affected by the pandemic, and this is the main reason why the authorities consider that the trend of evasion is increasing. In any case, this problem contributes considerably to the increase in the deficit.

Category	Impact/challenge	Description of the impact/challenge
	Handling and use of Transit Information	One of the great weaknesses of the system is the management of information. The behavior of demand within the zonal and BRT system is uncertain because the information is not obtained quickly and reliably. Although this problem comes from before the pandemic, during this, the lack of availability of this type of information played an essential role by not being able to carry out proper planning when it was required. By concession contract, the collection concessionaire oversees the collection of travel data of the users, however, this information is not correctly taken to the fleet management system, so the authorities cannot use it quickly. In the future, to carry out proper planning, it is necessary to have the tools to use this information and make the system more efficient.
Operational	Inefficiencies in the planning of the various modes of transport	In the coming years the transport system will increase its capacity supply considerably. Three new BRT lines, first metro line and 2 regional trains will be part of the system. Each project has an independent business model of operation, so the great challenge of this situation is the physical and tariff integration of these different modes and their respective financial sustainability. Nowadays it is planned that each project will have different rates and access cards so that users will be affected, mainly by the poor planning of the public sector. Likewise, many of the new systems such as the metro, will have a direct competition with existing modes such as the zonal system and BRT lines, in consequence for the same demand there will be a diverse transport supply that will increase transport costs and generate inefficiencies. This will lead to the dismantling of these systems and thus optimize the supply and costs of the system.
	Inefficiencies in long-term planning	The transport system has some inefficiencies due to the poor planning of the public policy in the long term. The whole system is thought in the short term. Each new mayor makes structural changes to the system that are not thought of for the future. For example, the tariff

Category	Impact/challenge	Description of the impact/challenge
		policy is not managed technically, but depends on the ideology of the government. In many periods the tariff has not been increased so the tariff deficit has risen in part because of it. On the other hand, the system is sized on a smaller scale, while the BRT line of the northern highway is designed for a capacity of 20,000 passengers per hour direction, in its operation it handles 50,000 passengers per hour direction. This is relevant because poor planning in the system infrastructure, in addition to inefficiencies, has generated a bad reputation among users that has encouraged their preference for other modes of transport. Thinking in the future, this topic becomes relevant to reduce costs and optimize the operation.
Institutional	Disarticulation among the authorities of the transport sector	According to the interviewees, currently there is a disarticulation between the transport management entity (Transmilenio S.A.), and the planning management entity (District Planning Secretary). Although the two entities are part of the district government, the interests of these two institutions are not aligned. While the secretary has political interests, Transmilenio S.A. has technical interests. This situation has led to inefficiencies and higher costs for the system. Additionally, with the new transport infrastructure, 2 new entities will be created, the metro company and the regional railway company, The latter entity will have the responsibility of leading the transport between Bogotá D.C., and its metropolitan area (13 cities). Therefore, transport governance in the city will be led by 3 entities. The general feeling of system agents is that the lack of centralized leadership to regulate the entire system will continue generating inefficiencies.
Reputational	Passengers feeling of safety and secutiry	Today the system faces a very important reputational problem. Due to the pandemic, people are wary of health in stations and buses. Additionally, due to the decrease in revenues and mobility limitations, the maintenance and expansion of the stations has been

Category	Impact/challenge	Description of the impact/challenge
		displaced. Finally, the economic situation of the country has generated an increase in robberies within the system, generating a general sense of insecurity. Public policy planners are analyzing the factors to which the user is sensitive to enter the system. As preliminary results they have found travel times, type of vehicle, user information and level of safety. The latter is playing a very important role and is making people decide to change modes of transport to private vehicles.

Table 2. Summary of the impacts and challenges for the upcoming year.

5.2. Strategies for the future of the system

5.2.1. Is a radical change in the system's structure necessary to make it sustainable in economic terms?

There is no general opinion among the interviewees about how radical the system change should be to make it more sustainable. For some, with the current structure and with minimal changes, the economic problem can be solved. For others, structural changes are needed. Otherwise, the system will not be sustainable in the future. However, there is a general view that specific system components require revision and adjustment. These components are related to additional income alternatives, institutional schemes, infrastructure, public-private partnerships, and operations.

5.2.2. Is it possible to operate the system without depending on subsidies (FET)?

Some interviewees agree that it is impossible to operate the system without relying on government subsidies due to its structure. Disorganized growth, non-centralized institutional design, tariff management under a political and non-technical perspective, and impact on demand due to the pandemic are some of the main reasons why the system is not in balance. Without an additional income source, it is impossible to stop relying on public resources. The district government is regulating other sources such as congestion charges and parking on public roads to help finance the system; however, in the opinion of several interviewees, these sources are not enough to cover the deficit. The only source that would be relevant to this case would be land value capture instruments, as well as real estate developments. Bogotá D.C. is a densely populated city, so the

real estate issue is essential for its organization and development. Currently, in the development of transport models, land-use models are not being considered, which generates an opportunity cost for the system and the city. For those interviewed who have analyzed this issue, there is a success story: the Hong Kong transport system, which generates a surplus in its operation, mainly for property development. In Figure 15, the income and costs of the Hong Kong public transport system show that it does not receive direct funding from the government but instead from its operation.

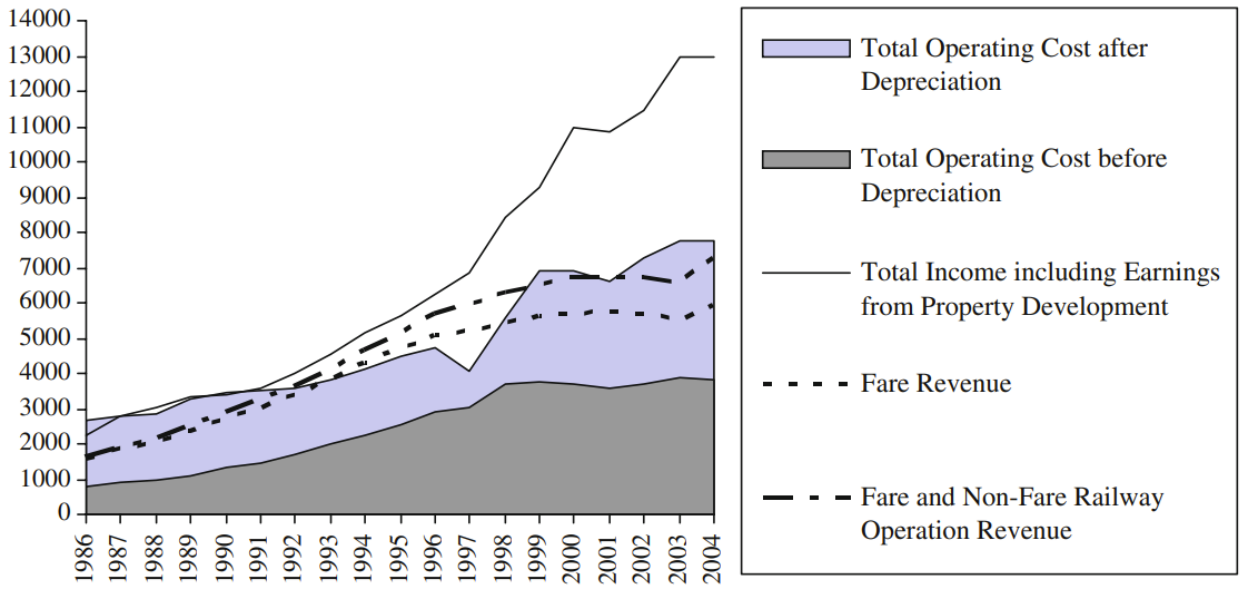

Figure 15. Income and operation costs of the Hong Kong transport system. **Source:** *Tang & Lo (2010). Pp 307.*

All in all, policymakers aim to generate new sources of income, not just from the operation. Nowadays, the government is trying to develop these kinds of tools and include them in infrastructure projects such as the first line of the metro project.

5.2.3. Strategies and ideas to ensure economic and operational sustainability of the SITP

All interviewees provided essential information for strategies and actions the transport system should implement to ensure sustainability. These ideas include institutional, revenue, infrastructure, and operational and structural changes. Planning a transportation system involves long-term adjustments, so most proposals won't be able to be implemented in the short term. To summarize all the recommendations, Figure 16 presents the current functional scheme of the mass

transportation system of Bogotá D.C., and the respective adjustments proposed by the agents interviewed.

Current functional structure

Ideal functional structure

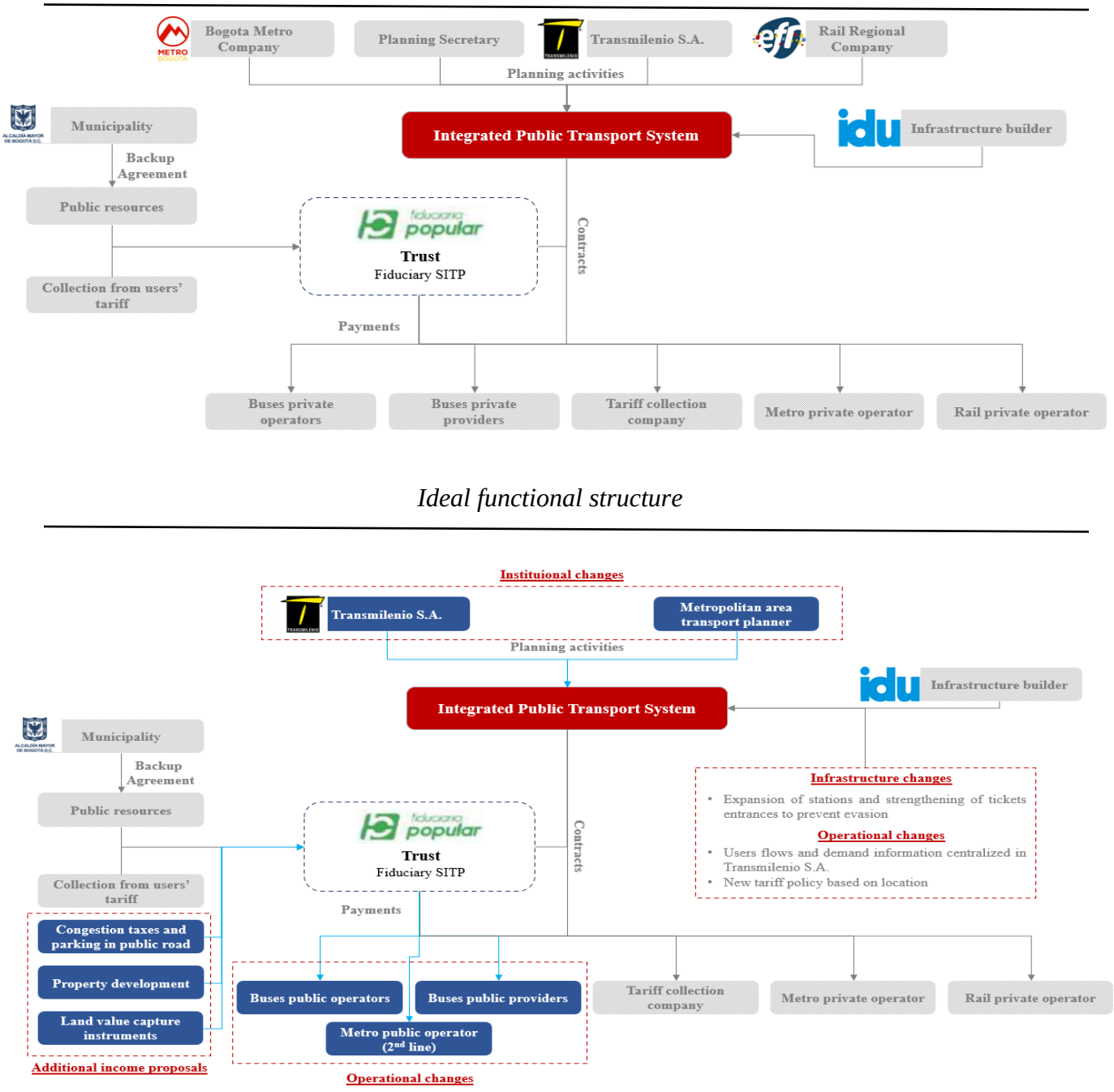

Figure 16. Current & Ideal Functional Structure

- **Institutional changes**

Currently, the planning of the system is led by four entities, the metro company, Transmilenio S.A., the Planning Secretariat and the regional railway company. For several of the agents in the system, this multiplicity of planning entities generates inefficiencies that do not allow an adequate long-term vision. Each new transport project, such as the metro or regional trains that will be in operation in the coming years, has independent business models and are not recognizing the existence of other system operators. Various planning entities with different incentives partly generate this situation. The significant problem of a divided and disjointed institution is the increased costs for users and the system. Consequently, the proposed change would consist of centralizing the planning of the transport system into two entities. Transmilenio S.A., with more than 20 years of experience in the management of transport in the city, should be one of these entities and the second could be a regional company. Both will involve the interests of the city and the 13 municipalities that make up the metropolitan area. In this way, the long-term planning of the system in terms of its operation, infrastructure and functionality would be led by entities that share interests. Likewise, the decisions of these entities should be free of political influences and focused on technical issues.

- **Additional income changes**

The revenue generated by the system from user tickets is not sufficient to sustain the operation of the system. As previously explained, the pandemic considerably affected the demand for the design, so policymakers are proposing the generation of additional income to finance its operation with the development of real estate projects. Following the scheme of successful cases such as Hong Kong, in which real estate developments maintain the system, there are specific proposals to apply these strategies in Bogotá, D.C. Currently, local authorities are implementing pilot projects for congestion charges and parking on public roads. The resources these measures will produce could be used to finance the system; however, for some interviewees, these resources would not be enough, while, for others, their massification in the city would generate an important source of income.

On the other hand, real estate developments and land value capture instruments should be the objective to alleviate dependence on public resources. Still, the big problem is that the authorities do not have the experience of legislation or the market to implement these measures. Even so, for

the metro project, these instruments were included in its execution so that in the coming years, the city will have the capacity to generate resources with this type of source.

- **Operational changes**

For the last 20 years, the transport system has operated under public-private partnership schemes. The private sector is responsible for the operation and provision of buses, while the public sector is responsible for planning and managing risks such as demand. There is great agreement among all interviewees that this scheme was essential to start operating the system because the government did not have the experience or capacity to manage these services. Nowadays, for many, Transmilenio S.A., has experience in being able to offer both operation and provision of bus services without requiring private intervention. In this way, the system could save the utility that the private charge for these services. The government is contemplating carrying out a pilot plan in one of the zonal bus corridors where the operator will be a public company. Although the generation of savings with this change could be substantial, it is relevant to indicate that the great challenge faced with this measure is that the private sector has much more agile conflict resolution mechanisms than the public sector. The idea would be to create public special purpose vehicles that offer bus operation and provision services independently. In the case of the second line of the metro, the option of the operator being Transmilenio S.A. is already being analyzed.

An additional proposal related to operational issues is the management of fleet and demand management system information. Currently, all the data from the buses is collected by the tariff collection concessionaire. However, this information is not reaching the government to make public policy decisions. For some interviewees, the poor supervision and planning of the system are mainly due to the lack of information, which generates higher costs as there is no way to optimize routes, or the kilometers traveled by the buses. An information system is essential for proper short- and long-term planning, so Transmilenio S.A. must centralize this function without delegating it to a private.

Finally, there is a relevant discussion about having different kinds of tariffs based on the locations of the stations. Colombia has a reliable information system in which people in situations of vulnerability and poverty can be identified. The rates should be lower for these people, and higher-income people who use the system at certain stations should have a higher fare. For many, the policy of a fixed rate today is not sustainable and must be reviewed and adjusted. To implement a

differentiated tariff policy, it is necessary to make an infrastructure adjustment in the stations. These changes consist of expanding the stations to ensure an environment of hygiene and sanitation, as well as changes in the inputs to the system. The latter is relevant because most of the evasion that the system faces is through the entrance . Likewise, it is necessary to adjust the stations to implement check-in and check-out systems and thus avoid perverse incentives for differential rate charges.

6. Conclusion & discussion

The thesis aims to identify the impacts of the pandemic on the public transport system in Bogotá D.C., and how it may be modified to ensure economic and operational sustainability in the post-COVID-19 era. Agents' and stakeholders' knowledge and experiences were qualitative analyzed to capture the impacts and to provide strategies for the future. The analysis done in this research extends previous studies regarding the impact of COVID-19 (Arellana et al., 2020, Ramirez et al. 2021, Caicedo et al. 2021, Dueñas et al. 2021), by collecting ideas and actions from experts about the system functionality to propose strategies that may be applied to improve it.

The Covid-19 pandemic generated a global disruption that affected most economic sectors. Indeed, the transport sector was one with the greatest effects, especially the aeronautical, maritime, and mass transport industries. This impact has been especially relevant in the case of the integrated mass transit system in Bogotá D.C. Colombia. According to Vickerman (2021), this situation has been repeated in all cities around the world with mass transport systems, which has pressured governments to ensure their operation during the pandemic with public subsidies. Although the SITP has required public resources in the run-up to the pandemic, the requirement for subsidies during the pandemic is considered by many to be excessive and not sustainable in the long term from a social benefit point of view. Therefore, this thesis has aimed to respond the following research questions: *"What are the effects of the COVID-19 outbreak on the public transport system in Bogotá D.C.?"* and *"What should be the modifications and strategies that the system could implement to ensure the economic and operational sustainability of the System?".* To do so, semi-structure interviews were performed with several agents and stakeholders of the system.

Regarding impacts and effects, the most important was the lower ridership level caused for the political decisions to control the spread on the virus and for the change in users travel behavior. In

addition, institutional, operational, economical, and reputational effects were also found. Most of them they were not necessarily caused by the virus, but their effect was aggravated by it. Nevertheless, all of them have created financial problems for the system by demanding higher amounts of public resources to finance the deficit. In this sense, all the proposed strategies are related to the respective effects generated or aggravated by the pandemic. Overall, the results obtained provide essential information that can be used by city policymakers to promote a more sustainable system. Likewise, this thesis has presented solutions to address part of the problems and challenges faced by the system, which in general will require a long-term transport policy. However, many more strategies need to be applied in the rethinking or redesigning to provide a sustainable and efficient transport service.

6.1. Limitations & future research

The research developed in this paper has several limitations. First, the sample of people interviewed may be considered as not fully representative. Although several agents and stakeholders were contacted for their opinion, it was not possible to schedule a meeting. This means that many agents relevant to the functioning of the system could not give their opinion on the strategies and challenges faced by the system. By interviewed more agents, it could have generated better public policy recommendations. Likewise, when analyzing only the case of the mass transportation system in Bogotá D.C. , all the results apply only to this system, so the conclusions cannot be validated externally in transport systems in other cities.

Considering that the qualitative data was analyzed in an exploratory way, the future recommendations are related to develop advance quantitative techniques and models. It could be interesting that for each strategy, its costs and benefits should be assessed and quantified to identify the social and economic benefit for each of it. In the same way, it is required to continue analyzing the effects that the COVID-19 outbreak brought to this new era. In general, the qualitative data must be accompanied by quantitative information to be used by policymakers to carry out proper public policy planning.

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8. Appendix

8.1. Appendix A. Set of questions

Impact of COVID-19

1. Considering your company's role in the Public Transport System of Bogotá D.C., which challenges influenced your operation during the COVID-19 outbreak?
2. In your opinion, what were the challenges brought by the pandemic to the system?
3. From your perspective, how would you evaluate the strategy that the authorities (Transmilenio S.A.) followed in responding to the effects of the pandemic?
4. Is the System facing any other kind of impact because of the COVID-19 different from those presented during this interview?

Strategies for the future of the system

5. What kind of economic & operational challenges do you see for the upcoming years of the system?
6. Do you think the system will be sustainable, considering the new reality in public transport, using the same structure as before COVID-19? In your opinion, is it necessary for a radical change in the system's design?
7. Is it possible to operate the system without depending on subsidies (FET) for the operation?
8. What actions, strategies, and changes should the system follow to ensure its economic and operational sustainability while minimizing the operation's dependence on subsidies (FET)?
9. Which factors limit the capacity to change the system and to be adapted to the new reality?
10. Should every agent and stakeholder of the system be involved in planning strategies for the future (How)?

8.2. Appendix B. Interviewees and their role

Company	Position	Name
Transmilenio S.A. / Financiera de Desarrollo Nacional (FDN)	Senior Planning Analyst / Senior Structuring Analyst	Josue Castano
Instituto de Desarrollo Urbano (IDU)	General director	Diego Sánchez
Treasury Secretary - Municipality	Former Secretary of Treasure	Carlos Alberto Sandoval
National Department of Planning	Sub-director of transport	Felipe Leon
Financiera de Desarrollo Nacional (FDN)	Project finance manager	Laura Botero
Fanalca – BMP – BMO (Operator and bus provider)	CEO	Juan Cajiao
Transinnova Usme S.A.S. (BRT bus provider)	CEO	Maria Cristina Guerrero
Electribus Bogota Fontibon (Zonal bus provider)	CFO	Diana Igua