TOOLS FOR THE MONITORING, USER CHARACTERIZATION, AND THEIR APPLICATIONS TO THE PUBLIC INTEGRATED TRANSPORT SYSTEM DUE TO THE COVID 19 DISEASE EFFECTS: A CASE STUDY IN BOGOTÁ, TRANSMILENIO COMPANY

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ABSTRACT

The pandemic made the transport system administration switch the way decisions were made in topics such as the response speed, resilience to shifts in the demand, and the new policy needs. Therefore, public transport requires monitoring tools, such as dashboards, and an emphasis in user characterization, in addition to traditional modeling and supply-demand indicators historically used by TransMilenio in order to command the operation of the public transport system of Bogotá D.C.

This study employed descriptive spatial and statistical analysis to comprehend the relations among the registers of contagion waves, user polls and the boarding information on SITP. Complementarily, the article shows the shifts in the demand towards the regulatory milestones for the pandemic, and how short-term changes in bus supply were made due to these set of regulations.

The paper also provides a recap of the international discussion about the occupation, efficiency, and biosecurity of massive public transport systems. The main results for TransMilenio were some supply changes, among others.

1. INTRODUCTION

The entity in charge of planning and coordinating the public transport system of Bogotá D.C, Empresa de Transporte del Tercer Milenio – TRANSMILENIO S.A., has three different services. The first one is the worldwide known as BRT, with a fully dedicated lane, central stations, high floor buses, and payment outside the bus. The second one is a conventional bus service with validation on board that covers the demand of the zones where there are not BRT lanes, carrying people from their neighborhoods to the BRT stations, making last mile solutions or trips to remote places in Bogotá's rural zone. The third one is TransMiCable, which is a cable system included statistically in the demand of the BRT and serves the locality of Ciudad Bolívar. The TRANSMILENIO system comprises 761 articulated buses, 1,323 bi-articulated buses and 273 dual standard buses for the BRT, as well as 7,105 bus services with validation on board and 160 cabins for the cable. Fig. 1 illustrates its geographical distribution through Bogotá.

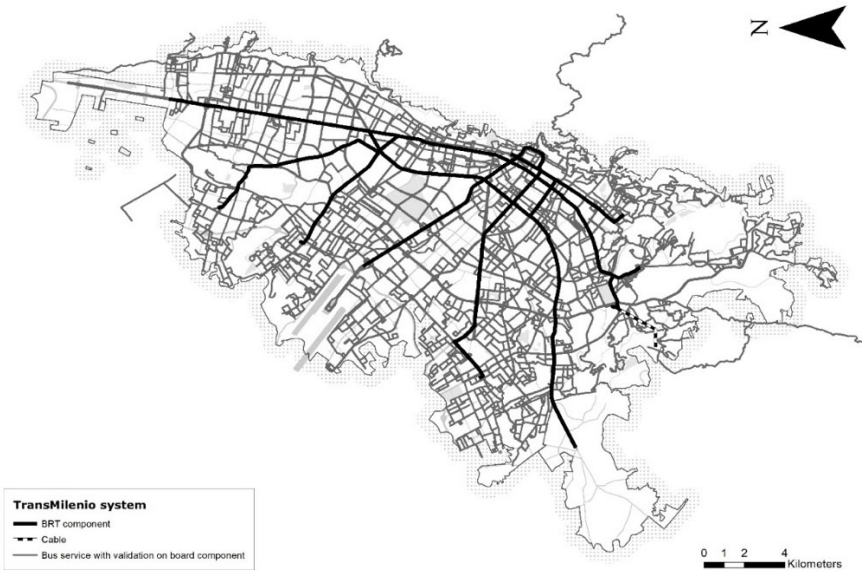

Figure 1: TRANSMILENIO: BRT system and on board validation bus service

Trying to predict the dynamism of a contagious disease is not an easy task, however, getting as close to reality as possible through models and analyses, such as those shown in this study, is an effort that can save human lives (Gomez, Prieto, Leon, & Rodríguez, 2021). For the purposes of this paper, people decide in the way described before. For a university council, it can be rational to order scaled schedules for on-campus lessons, because they want to prevent desertion and maximize learning, restricted by the capacity controls imposed due to the pandemic and the probability that an outbreak starts in the campus. For a student, the choice related to the self-care measures works in the same way. If the student considers that going to the campus is too risky for their life or for the life of people who live with them, the student will choose not to go, even if the place is open. On the other hand, if the student thinks that only by wearing mask, they will be able to protect themselves from COVID-19,

they will more probably go to the campus, given the choice of the university council. In the student's example, the information and the context play a role on how they make their decisions. This mechanism of decision is similar to the one described by Przybylowski, Stelmak, & Suchanek (2021). In that way, each individual's decision plays a key role that has to be taken into account when modeling demand.

2. LITERATURE REVIEW

This chapter included three focuses: The first about de pandemic and public transport, the second on geographic information systems and their use with infectious diseases and finally, the third on changes the individual preferences and behavior.

2.1 Literature about the pandemic and public transport

The reviews and recommendations about COVID-19 and the challenges of public transportation indicate a general context about the service and the risk for users (Gutiérrez, Miravet, & Domènech, 2020). Likewise, changes in the demand for transport modes were evident, as well as the decrease in public transport systems (Le , Sheng, & Sharp, 2021) (Komla Junior Dzis, Obeng-Atuah, Ackaah, Yaw Tuffour, & Eric Aidoo, 2021) and research needs (Gkiotsalitis & Cats, 2020).

The case studies during COVID-19 about the effects on public transport show a global problem that includes analysis of supply, demand and biosecurity, in countries like Turkey (Devecí, Aydin, & Kusakci, 2021), Finland (Tiikkaja & Viri, 2021), Poland (Przybylowski, Stelmak, & Suchanek, 2021) and United Kingdom, regarding the future of public transport (Vickerman, 2021).

2.2 Literature on geographic information systems and their use with infectious diseases

In 1854, an English doctor named John Snow, through the spatial location of cholera cases in London, managed to realize a pattern that until then no one had noticed, thus discovering the source of the outbreak of the disease in a water pump of the place (Fradelos, Tsaras, Papathanasiou, & Kleisiaris, 2014). Although geographic information systems did not exist in 1854, this example makes it clear that having information on a map allows us to ask ourselves questions and solve problems, as we do with current tools.

Another investigation on the spread of hepatitis C was carried out in Connecticut (Navarro, Trooskin, & Hadler, 2005) through cluster analysis. This study was able to identify clusters in the most densely populated urban areas, which had previously been identified as areas of substantial injection drug use. Although local demographic characteristics alone do not follow a particular phenomenon, crossing them with other geographic variables helps to prevent disease transmission.

Currently, with the COVID-19 pandemic that can affect a population very quickly, it is necessary to have a solid support of spatial information for decision-making, formulation of measures and evaluation of the effectiveness of prevention and control of COVID-19 (Zhou, y otros, 2020). Considering the above, the cities with updated information day after day on dashboards, and maps on the location of infections and availability of care in medical centers for decision-making are those that have the least consequences to regret.

2.3 Changes in the individual preferences and behavior

A preference is a comparative evaluation of a set of objects and works as a cognitive marker that reminds people how to interact with the environment. The objects of preferences are not given for being organized but are those that can be perceived by a human being, whose experience allows to differentiate, and those which a human being's cognitive capacity can remember (Druckman & Lupia, 2000). In the case of the preferences for a contagious disease, as COVID-19, the preference for staying home or going out to work depends on factors such as the education received by the person related to viruses, their risk tolerance, among others. Thus, two people who receive the same information about a first case detected can react in two different ways.

The rational choice theory is an approach founded on methodological individualism (MI), from which human behavior is explained. The MI starts its analysis with the principle that social behavior reflects the choices everyone makes. For that reason, the individual behavior determines the social outcomes. In this paper, we suppose that choices made by everyone, such as deciding to work or not, or by each person with agency, e.g. a university headmaster, can impact the results in activities related to occupancy of public transport. Back into the ration choice theory, Elster (1996) says that the social behavior responds mainly to the decisions made individually, which are the consequence of a rational thought. This is an instrumental rationality, which means that people use reason to obtain something they want. In this sense, a choice is rational if it maximizes o minimizes certain objective people trace for themselves, with a given context, rules, as well as other types of restrictions, e.g. the income level or the education you received.

For example, in the case of COVID-19, your rational choice can be guided by the principle of minimizing the probability of being infected, while having to do an essential job (e.g., a nurse), or maximizing your personal income, given some restrictions to your individual behavior. Once the person identifies the rule of decision, the decisions of public health are linked with people's personality (Blagov, 2020) or a consequence of the current political discourse with which people identify (Hatcher, 2020). A rational choice explains each one's behavior as the decisions made to accomplish that rule. Therefore, the rationality, in this case, is guided by the results an individual plans to obtain.

3. SUMMARY OF THE INTERNATIONAL BENCHMARKING

This chapter is divided into two parts, the first on benchmarking of the policies of the pandemic and the second, benchmarking of the occupancy.

3.1 Benchmarking of the policies adopted in the early stages of the pandemic

The benchmarking is presented in Table 1, this includes cities of the five continents about transport system and strategies used in pandemic.

City	Country	City popul.	Urban area of the city	Type of public transport system	Strategies used
Sidney	Australia	5,3 millions of inhabitants (2018)	12367,7 km²	9 subway lines and one train line	There is no capacity to clean en-route buses during shifts. They requested to avoid travelling during rush hours if possible and to limit travels to those who are strictly necessary.
Lima	Peru	8,8 millions of inhabitants (2017)	2672,3 km²	2 subway lines and 5 BRT lines	Since Monday, March 16th, 2020, only BRT operates, the other systems are closed. BRT is working with the Saturday schedule with difficulties for the transport of operators. Cleaners and all employees of the system have gloves and masks.
Shenzhen	China	12.53 millions of inhabitants (2017)	1748 km²	8 subway lines and bus system	Buses are disinfected after each trip. At night, some routes are suspended. Floor markings (also adopted in Europe) are used as a guide to minimum distances between passengers for social distancing.
Madrid	Spain	3,2 millions of inhabitants (2019)	604,45 km²	13 subway lines, tramway and bus system	The transport offer must be reduced to at least 50%. The subway prioritized stations near hospitals. The use of the two lines of seats closest to the driver is prohibited.
Santiago	Chile	6,25 millions of inhabitants (2017)	837,89 km²	7 subway lines and bus system	Buses are sanitized more often. From March 22nd, 2020, they adjust and reduce the hours of operation.
Singapore	Singapore	5,6 millions of inhabitants (2017)	697 km²	6 subway lines and bus system	Two campaigns: (1) protect employees by disinfecting drivers' seats and the use of protective items such as gloves, and (2) avoid contact with employees at information points as much as possible, which includes "safe distancing".
Kuala	Malaysia	7,59 millions of inhabitants (2016)	243,65 km²	BRT system	They took temperature measurements of the drivers and the system team before starting the shift. In addition, the hygiene days of the buses and the system facilities tripled.
Jakarta	Indonesi	10,3 millions of inhabitants (2017)	750,28 km²	6 train lines and a bus system	They reduced the service of the TransJakarta system: 248 routes were reduced to only 13 with buses traveling every 20 minutes.
Buenos	Argentin	3 millions of inhabitants (2017)	203 km²	6 subway lines and a bus system	Long distance trains and buses suspended their services. Buses and trains in the Buenos Aires metropolitan area operated only with seated passengers

City	Country	City popul.	Urban area of the city	Type of public transport system	Strategies used
Stuttgart	Germany	634 830 inhabitants (2019)	207,36 km²	train and bus system	The trains reduced their frequency to every 30 minutes; there are no night or weekend buses. Service to and from the airport was suspended. Payment in cash was prohibited. The ascent-descent of passengers is only allowed through the farthest door from the driver.
Panama City	Panama	880 691 inhabitants (2013)	275 km²	2 subway lines and a bus system	They included maximum capacity for buses and distance marks inside the buses. The "adopt your hero" campaign was implemented to raise awareness about the drivers' work. They disabled the seats closest to the driver and the rest of the interleaved-use seats.
Curitiba	Brazil	1, 8 millions of inhabitants (2015)	412 km²	BRT system	Initially, they reduced the supply of buses but since the quarantine was not official, the system had to increase the supply again due to demand.
San [illegible]	U.S.A	805.235 inhabitants (2010)	121 km²	Light train and bus system	The frequency of the service was reduced and if the buses are full they will not stop to pick up passengers. Additionally, there was a reduction in routes.
Paris	France	2,18 millions of inhabitants (2017)	105,4 km²	14 subway lines, 13 train lines, 11 tramway lines and bus system	The frequency of the routes was reduced and they generated a real-time report of the offer of each of the transport services.
London	England	9,7 millions of inhabitants (2018)	1572 km²	11 subway lines and bus system	Metro stations are closed and using the system is only recommended if essential. They suspended the subway service on Friday and Saturday nights, but the bus service continues to operate for essential workers. They suspended the service in the city center and communicate by email with registered users
Vancouver	Canada	2,2 millions of inhabitants (2016)	114,97 km²	3 skytrain lines, SeaBus (ferry) and bus system	The free service was implemented. There was a change in frequencies. In addition, the entry and exit of passengers was required only through the back door or the one furthest from the driver. They increased the disinfection of buses per day.

Table 1: Policies adopted at the beginning of the pandemic by COVID-19

3.2 Benchmarking of the occupancy

After adopting some of the decisions mentioned above, TRANSMILENIO S.A. faced a new situation, in which the economy was progressively being reactivated. At the international level, there were restrictions to the occupancy of public transport, in cities such as: Shenzhen, where the limit in place was of the 50% (Ma, 2020); Jakarta, where public transport was shut down and then, on June 8th, 2020 opened at 50% of its capacity (Widadio, 2020), or Mumbai, where the occupancy limit was also 50% (Mumbai Mirror, 2020). At the national level, the order was to have a 35% capacity limit. The main reason to do this was that the local health authorities considered that public transport could be a place where massive contagion clusters of the virus SARS-CoV-2 could appear.

However, more international evidence about the behavior of the contagion clusters started to appear and it suggested that public transport was not as risky as thought. First, discussing the recent epidemics caused by other Coronaviruses (SARS and MERS), Avineri, Musselwhite, and Susilo (2020) argued that there was no significant evidence of reduction of the contagion in the cities that closed their transport system.

Second, referring to the COVID-19 pandemic, the evidence collected from the tracking and contact tracing strategies did not suggest a statistically relevant effect of public transport on contagion. For example, Japan, at the beginning of its outbreak, followed a strategy that consisted in detecting contagion clusters. Despite its robust contact tracing strategy, no single cluster was detected in passenger trains (Normile, 2020). Likewise, in New York, from 1300 patients admitted with positive COVID-19 results, only the 4% of them affirmed to have used public transport in recent days (Shwartz, 2020). With those results, the next step was to ask why public transport seems safer than other crowded and enclosed places. Fig. 2 shows the overall map of the cities consulted.

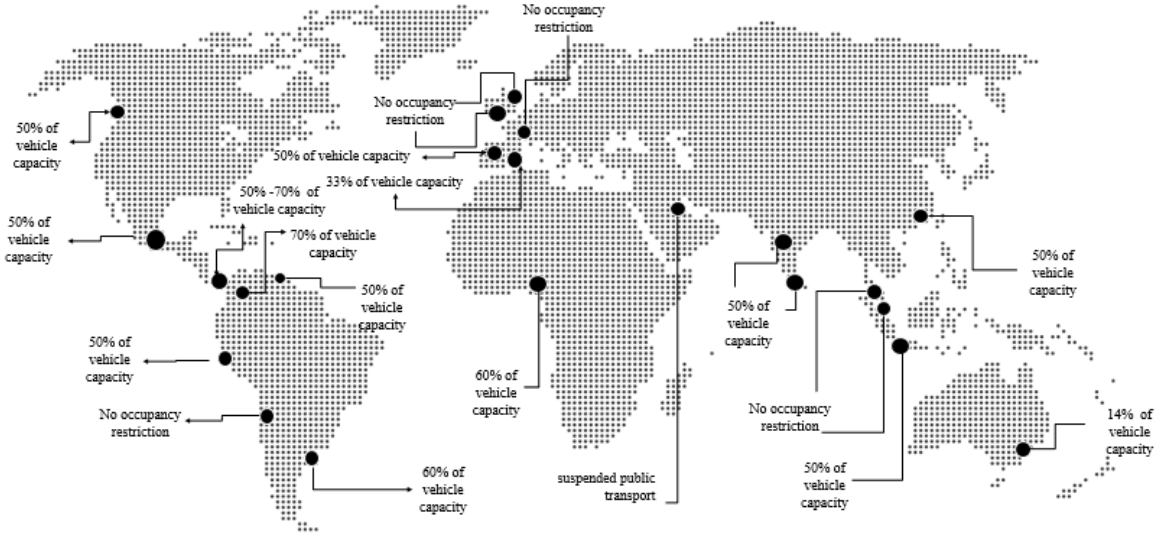

Figure 2: Map of the consulted cities

The evidence found suggested that the transmission of the virus is low, if users wear their masks in the appropriate way and if they do not talk at all during their trip, although the evidence was not yet conclusive (Tirachini & Cats, 2020). Even though inside the vehicles, that are enclosed places, there are concentrations of people who do not keep the prudent distance, but the implementation of other non-pharmaceutical measures, such as the use of mask or the prohibition of speaking (as in the case of Singapore), helps to reduce the probability of contagion (Tirachini & Cats, 2020). Attending to these data, in Colombia the occupancy limit went from 35% to 50%, while trying to ensure that people could make the appropriate decisions about the use of masks, and silence, for protecting themselves from the virus.

4. INSTITUTIONAL POLICIES ADOPTED

This section explores the different measures and strategies adopted by TRANSMILENIO S.A. in response to the pandemic, and the need of reducing the occupancy of the system. First, there were a set of sanitary measures that intended to reduce the contagion probability, as well as other that were meant to increase the supply of the system. The second section shows some demand management strategies that were implemented with other public offices.

4.1 Sanitary measures

Given the importance of mobility in a city, the district entities in this sector must face the critical impacts of the coronavirus, making a change in demand that contributes to the safety of passengers and operating personnel of the system. TRANSMILENIO S.A. focused its service on measures that promote social distancing and biosafety standards in accordance with the regulations issued by the Nation and the District. Therefore, the maximum offer of the system was modified, a monitoring tool with public access was generated and cooperation measures were agreed with other entities to characterize users, among other strategies that are detailed below. The measures were related to the resolutions issued at the national level.

On March 6th,2020, the first case of COVID-19 was diagnosed in Bogotá D.C. By March 12th, there were already 5 cases diagnosed and a yellow alert was emitted. In Bogotá, people started to diminish the use of public transport. On March 16th, an orange alert was emitted, and some temporary bike lanes were made by the city administration. Afterward, the national government announced a “national quarantine” since March 25th.

The government started to permit the opening of some economic activities since April 27th until July 13th, when the city administration made localized confinements, so that part of the city could maintain the economic activities, while the other was in a strict confinement. On August 28th, this policy ended and, on September 1st, another policy called “Nueva realidad” (New Reality) started, which limited de working days per economic sector, and

assigned entrance and exit hours for each one of them. The regulations were modified slightly during the next months, until almost the whole scheme was derogated by November. Fig. 3 summarizes the policies implemented.

Decree	Expedition date	Measure applied by TRANSMILENIO S.A.
081, 2020- Sanitary measures	11th March 2020	Installation of 134 portable sinks Daily washing and disinfection of stations and buses
087, 2020- Public calamity	16th March 2020	Pedagogical prevention activities
090, 2020- Vital Drill exercise	19th March 2020	Fleet coordination Demand reduction (87% BRT component and 80% bus service with validation on board component)
457, 2020- Mandatory isolation	22nd March 2020	Creation of the public control board Control of user influx Mandatory use of face masks in the system System offer between 50% and 75% from March 20th to April 29th, 2020 Health routes
593, 2020 and 121, 2020 - Opening of economic sectors	24th April, 2020 and 26th April, 2020, respectively	User characterization New access scheme to critical stations Chair marking Offer increase to 100% Demand management app - "Full bus"

Table 2: Decrees issued by the District of Bogotá for COVID-19

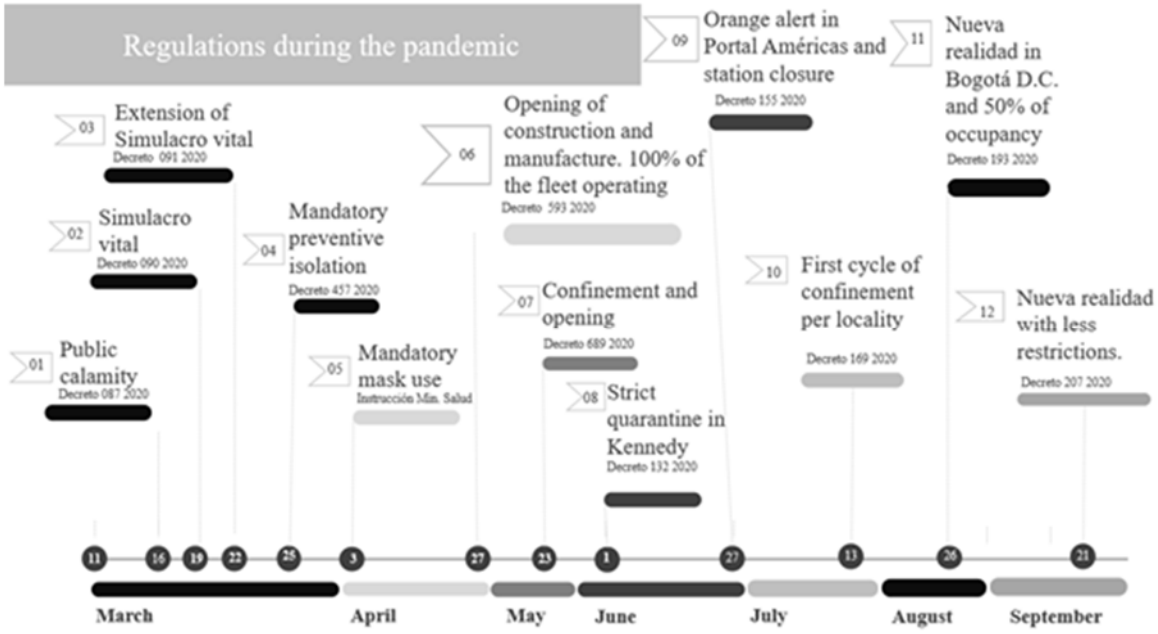

Figure 3: Timeline of the general policies implemented

4.2 Demand management: Public officers' demand management and Universities

An additional policy implemented by TRANSMILENIO S.A. and Bogotá D.C. was to organize public employee's schedules in different turns, as well as pilot schedules for some universities. Due to the occupancy limit of 35% (and then 50%), if activities were to be made in person once again, the transport system would not have been able to maintain a low occupancy, especially in some points of the city and during rush hours.

The most important schedule was developed with the Departamento Administrativo del Servicio Civil, the entity that regulates the exercise of public employees in Bogotá D.C. They designed a survey which asked, first, basic data, such as the institution they worked for, their municipality and department of residence, and, if the place of residence was Bogotá, their locality, and the planning unit they lived in. Second, there were some questions about the days of the week they worked and the mean of transport they used. On the following lines, there is a brief illustration of the descriptive statistics relevant for TRANSMILENIO S.A. As of June 23rd, there were 12.329 observations of the survey, but the size of the sample was different, according to the institutions where the instrument was applied. Fig. 4 represents the day of the week in which the public servers work, according to this survey.

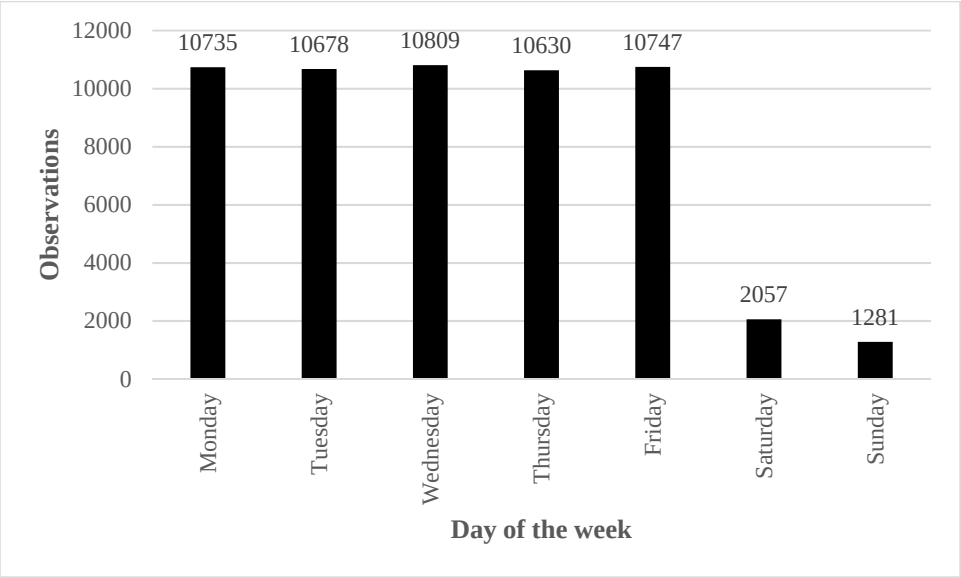

Figure 4: Day of the week in which the officer works

In general, it was observed that most public servers worked from Monday to Friday. Most of the records corresponding to Saturdays and Sundays belonged to health sector workers. This pattern indicated that some of the district servers could work during the weekends, without adding extra pressure to the system occupancy. This aspect depended on how they made their risk-benefit balance and took the most rational decision to maximize that benefit, while minimizing the risk of contagion, given the restrictions that could be held at that time.

However, to obtain internal validity, these analyses need to be representative of the level of the entities and must provide information about the number of people that could use the

system. In this way, it could be possible to make projections and formulate alternatives for schedules and labor days, according to the impact of the demand generated by public servers on punctual zones of the city, close to their workplaces. Assuming that the collected sample was representative and using the data that belongs to the Departamento Administrativo del Servicio Civil of the number of public servers per entity in Bogota, an expansion factor was generated from the sample of the institution. With the obtained data, the analyses that required orders of magnitude were performed.

The first graph on Fig. 5 represents the percentage of district servers who answered if they used the on board validation bus service, at least, one business day of the week, to transport themselves. A percentage of 39% of them answered that they did use it.

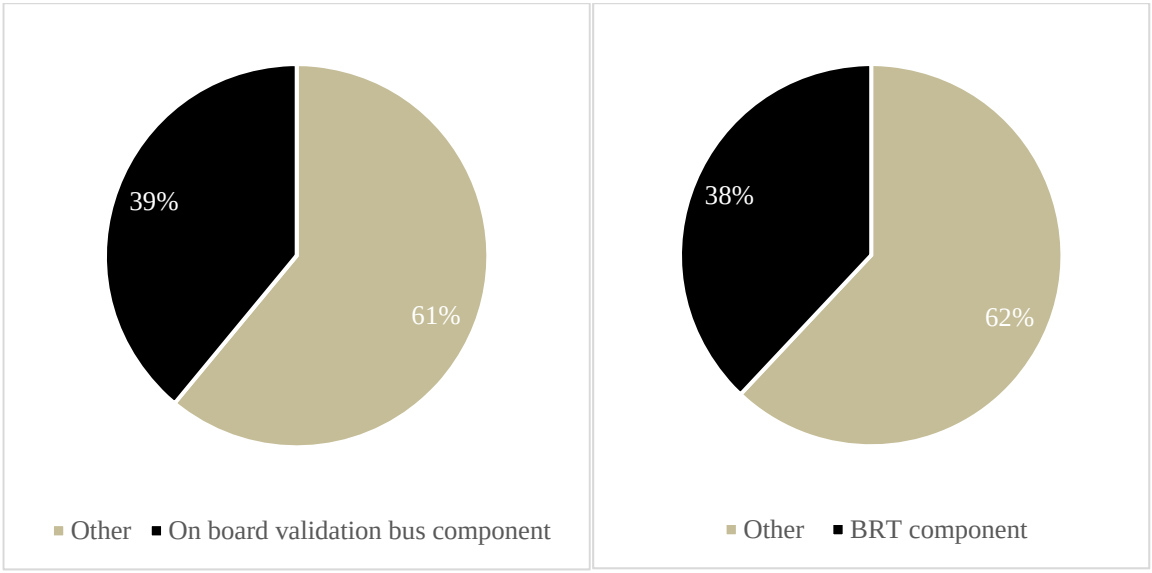

Figure 5: Use of the on board validation bus component and the BRT component

Since the public employees could answer with more than one means of transportation per week, it is not possible to distinguish either if someone used both system components or if they had a main mode of transportation. This means that the data of both components should be analyzed separately. The second graph on Fig. 5 represents the percentage of district servers that answered if they used the BRT, at least, one business day of the weekend, to transport themselves. A 38% of them answered they did use it.

These preliminary data indicated that the expanded sample of public employees of Bogotá D.C. could be subjects of interest for TRANSMILENIO S.A. Initially, these possible trips were used to identify the zones with more density of district employees who made trips in the transport system. This is the most relevant geographic information used to build the maps shown below.

Fig. 6 shows the spatial distribution, and the magnitude of the trip attraction zones. They are in the same spots where there is a big concentration of public employees, or public hospitals.

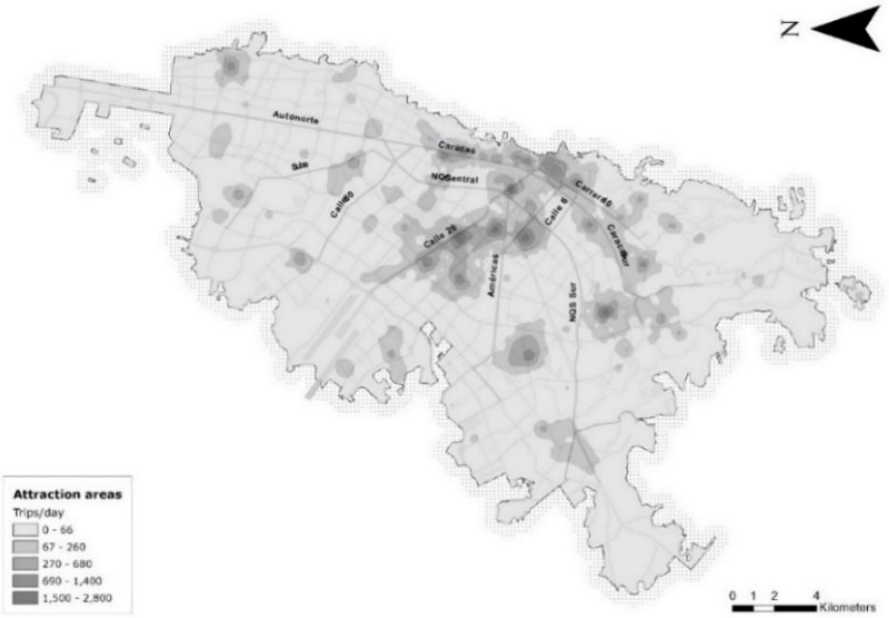

Figure 6: Geographic distribution of public officers

Afterward, the team assigned the expanded observations of the survey to the nearest bus stop, for the Bus Rapid Transit (BRT), or bus stops for on board validation bus service, of the surrounding area. If there were two or more nearby bus stops or stations, it was supposed that their demand was distributed in the same way as the demand of a normal day, punctually, March 11th/2020. For example, A and B are two stations, and on March 11th/2020 the demand of A+B was of 100 passengers. A total of 60 of them went to A, while 40 of them went to B. This means that, for entity E, which is in between A and B, the team assigned 60% of the demand entity E generated to A, and 40% to B. Fig. 7 illustrates this process with the BRT.

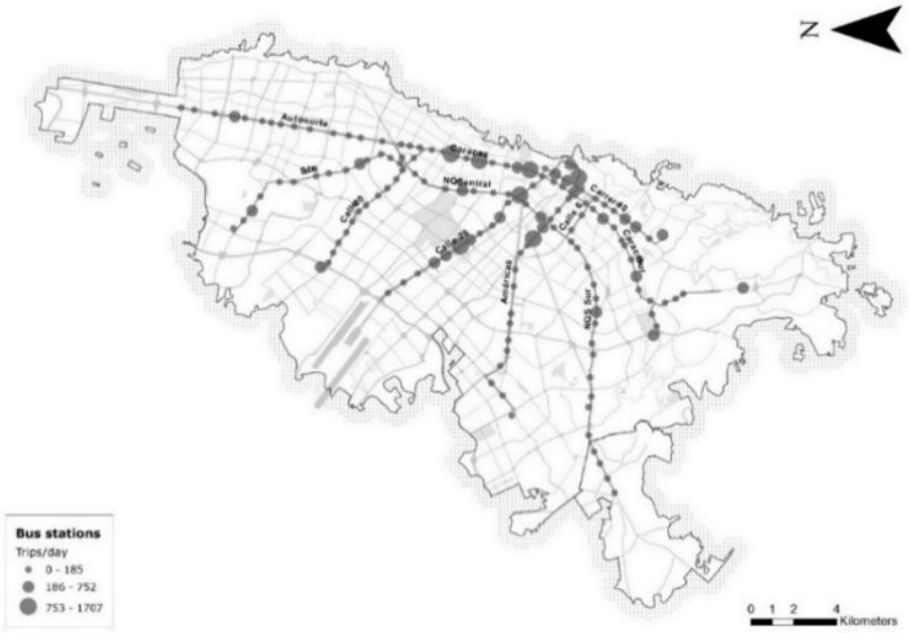

Figure 7: Geographic distribution of public officers. Trunk component.

The stations that would probably receive more demand from public servers were Museo del Oro, Calle 34, CAD, Concejo de Bogotá, Salitre-El Greco, and El Tiempo-Maloka. The process was repeated with the bus stops of the on board validation bus service, and the results are shown on Fig. 8.

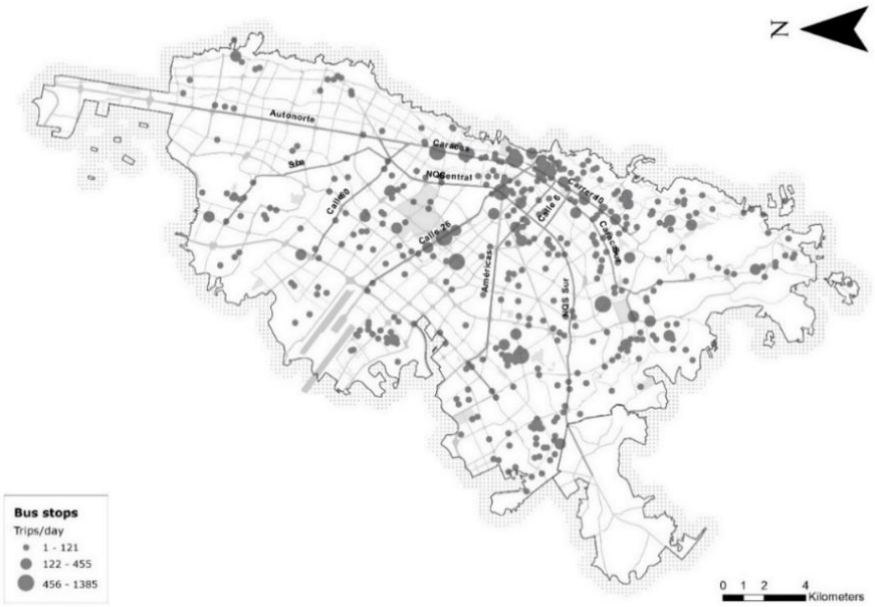

Figure 8: Geographic distribution of public officers. Zonal component

However, the analysis of the on board validation bus service was not considered, because it was close to surpass the current threshold set by the local government, that is, the 35% of the occupancy. For the BRT, the team made a projection of the maximum additional demand that the public employees could represent, given that 38% of the public servers, in average, would rather choose to use it. The value obtained was added to the demand profile observed recently, for visualizing at what times of the day the demand could get over the 35% limit. Fig. 9 represents the results obtained for the CAD station.

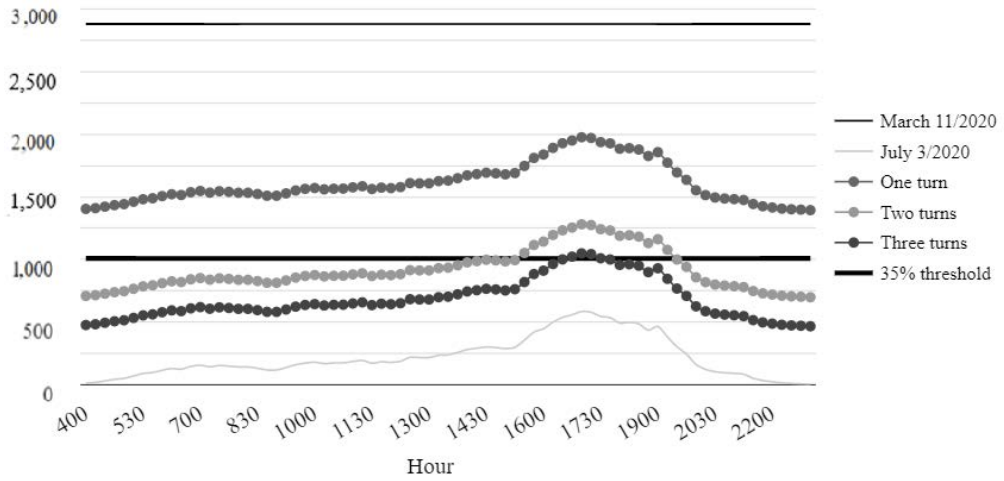

Figure 9: Scenarios for the CAD Station

The uppermost or first horizontal line represents the maximum number of ticket validations observed during an hour on March 11th /2020, day in which the system reached its highest demand on the year. The second line represents its 35%, which was the threshold in July. The light gray line shows the volume of ticket validations observed on July 3rd, which was the day when the maximum demand was observed after the first confinement. The first dotted line represents the biggest extra demand that the station could receive during an hour if all public employees in Bogotá D.C, registered in the Departamento Administrativo del Servicio Civil, went out at the same time. The second and third dotted lines expose how much variation on the hourly demand could be observed if these people went out of their jobs in two or three different, but equal in the number of employees, turns, etc.

The second profile can be interpreted as public employees who worked close to the CAD station and divided into three equal groups at the end of their working day. In this case, the station could surpass the 35% threshold at, about, 17:00. Consequently, TRANSMILENIO S.A. recommended that the institutions located near CAD returned to in person activities in two or three turns, but avoiding the station rush hours (15:30 to 19:30 for two turns, or 16:30 to 17:30 for three turns). This process was repeated with the other stations selected.

The analysis for the universities was made in a similar way. First, the team took data from the Encuesta de Movilidad 2019, which is a survey made by the mobility authority (Secretaría Distrital del Movilidad-SDM) and contains information about the purpose of the trips and the zones that attract them, among other aspects. Two simulation scenarios were formulated. In the first of them, the total trips with going to study as main purpose were considered to add them to the observed hourly demand profile on July 3rd/2021. The objective was to predict the best and the worst hours of the day for planning massive trips, according to the decisions of the universities, which would probably aim to maintain a low occupancy of their campus, with the rationale mentioned in the literature review. This occupation was supposed to be of about 50%, 30%, or even 10% of the normal occupancy. That extra demand was added to the observed profile, thus representing again a threshold of the 35% of the demand observed on the maximum demand hour of March 11th/2020. Fig. 10 represents the main scenarios.

The line marked with Univ_50 represents the scenario in which the universities restrict their occupancy to the 50% of their campus' capacity, supposing that all students who assist go out at the same time of the day. The reader can observe that, during rush hours, the demand ff the whole system could surpass the 35% occupancy limit, when adding linearly the extra demand to the observed demand profile of July 3rd. The other lines show that, if the campus capacities were lowered, the impact on the whole system would be small enough for it to respect the imposed threshold. But the question about what could happen to the stations located close to the campuses remained.

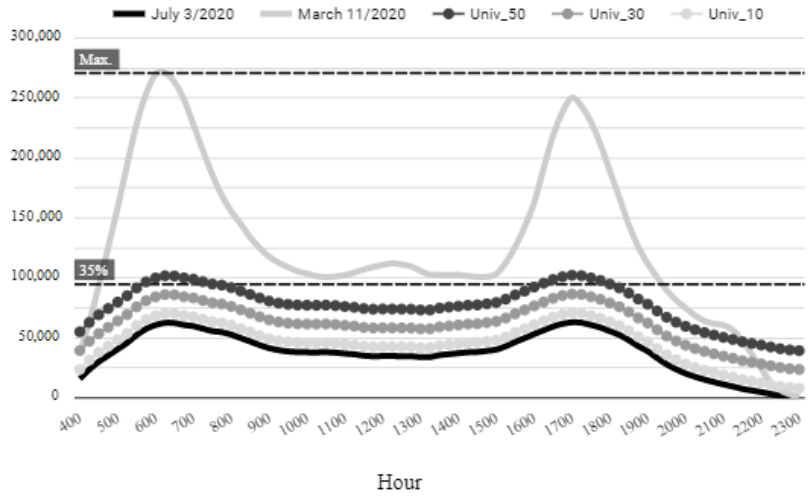

Figure 10: Potential extra demand due to the return to presential activities universities

The second scenario tried to answer it. The database provided by the SDM had also information disaggregated by Zona de Análisis de Transporte (ZAT), which are geographic demarcations of the territory that contain trips of people with similar conditions. The ZAT located downtown, in the historic center, were eligible for the analysis, because that zone concentrates most of the private universities. For each one of them, the team calculated the percentage of trips per purpose, and chose those ZAT where the trips that had "education" as their purpose were predominant. Then, we took the sum of the expansion factor of the observations that had education as their purpose and assigned them to three stations located in the area. (Museo del Oro, Las Aguas and Universidades), with the same three occupancy restrictions. Fig. 11 shows the result, with the same 35% threshold.

It can be observed that, although the scenario with the 30% of the normal occupancy of the campus do not exceed the threshold imposed to the system, the limit is surpassed in the stations that attend the ZATs analyzed. So, as in the case of the public employees, the recommendations had to seek to change people's behavior in a sectorized way

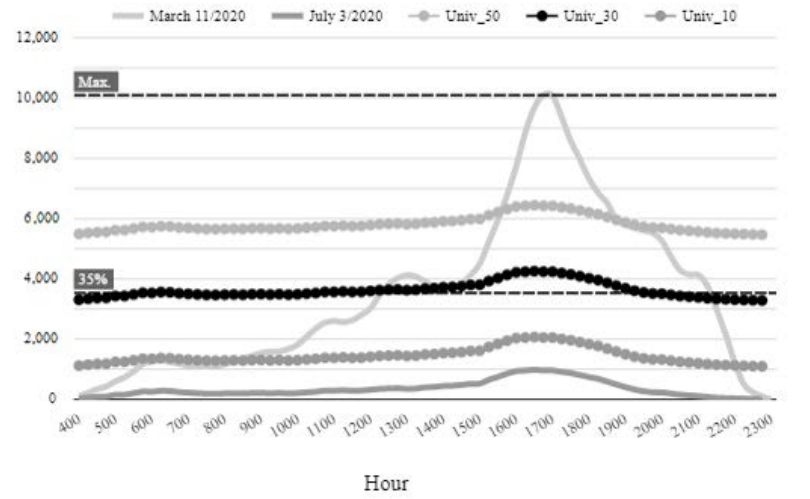

Figure 11: Change in the demand if universities return to presential activities

5. RESPONSE OF THE DEMAND

This chapter has three sections, the first is about the context in which this study identifies the variation of demand, the second is about vulnerability to COVID-19 for the transport system and finally, the third is the main section in this paper about demand graphical analysis.

5.1 Context

The transport demand was heavily affected by the collective and administrative response to the COVID-19 pandemic. Fig. 12 illustrates the daily behavior of the demand from March 1st/20 through March 26th/2021.

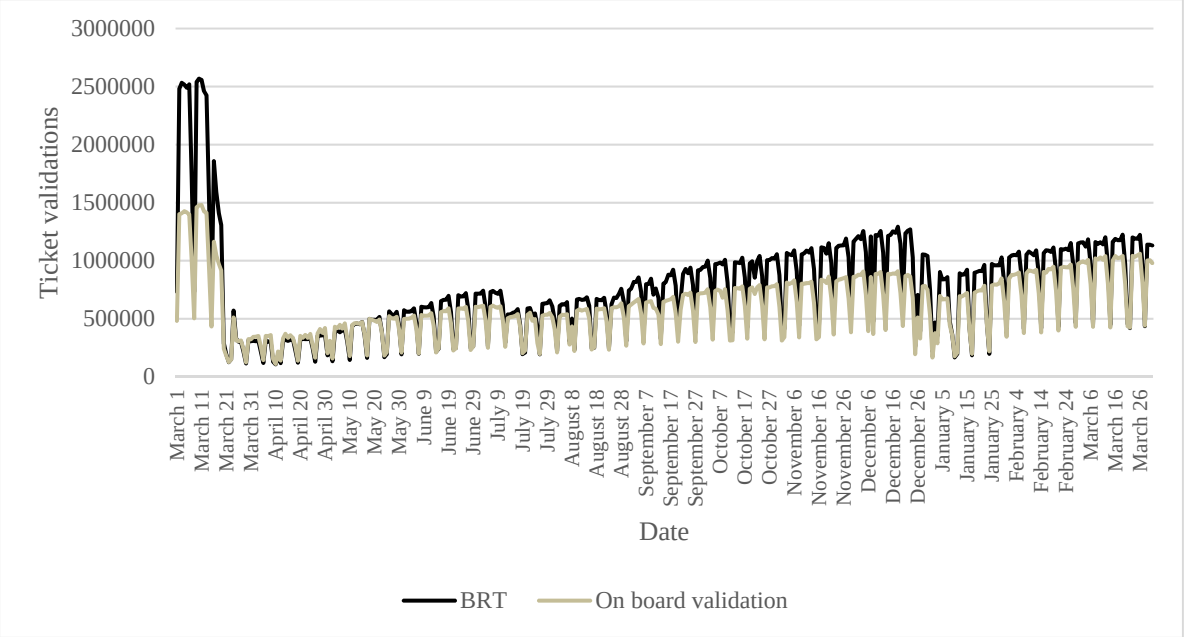

Figure 12: Comparison of the demand of the BRT and on board validation bus service.

It is possible to observe a reduction of the demand since March 12th/2020 y until March 19th/2020, which reflect a modification in the behavior due to the announces of the pandemic. On March 6th/2020, the first case of COVID-19 was diagnosed in Bogotá D.C. During those days, the demand maintained stable, and reached its annual peak on March 11th/2020. But, by March 12th there were already 5 cases diagnosed and a yellow alert was emitted. In Bogotá, people started to diminish the use of public transport. But the tendency went steeper when, on March 16th, an orange alert was emitted, and some temporary bike lanes were made by the city administration. We assume that, during those days, the reduction of the demand was caused more by the announces made by the authorities, rather than by impositions. It was rational for Bogota´s habitants to avoid the crowded places and the contact with other human beings, so they started to make choices to protect themselves. The steep decline of the demand was followed by the enforcement of a “simulation of isolation”, which was meant to prepare the citizenship for a prospective confinement There is a small

peak of demand on March 24th, because it was the last normal workday of the year. The national government had announced a “national quarantine” since March 25th.

The demand dropped to previously unsuspected levels but started recovering even before the government started to permit the opening of some economic activities (April 27th), but then is when demand started increasing progressively. This tendency was maintained until July 13th, when the peak first wave of the pandemic was taking place. The policy adopted by the city administration was to do localized confinements in some localities, in a way in which part of the city could maintain the economic activities, while the other was in a strict confinement. The demand dropped initially but recovered in a small proportion during the next day. On August 28th, this policy ended, and, on September 1st, it started another one called “Nueva realidad” (New Reality), which limited de working days per economic sector, and assigned entrance and exit hours for each one. The regulations were modified slightly during the next months, until almost the whole scheme was derogated by November. The demand increased in a steeper manner than the one observed previously, and kept doing it until December 18th, when the Christmas celebrations had started. That is a normal seasonal change observed in year by TRANSMILENIO S.A. Then, from January 5th to January 28th, there was another cycle of localized confinements, but the demand grew during all the time, until March, when the increasing tendency started to stabilize.

5.2 Vulnerability to COVID-19 and the transport system

The entity responsible for the planning, collection, processing, analysis and dissemination of official statistics of Colombia, Departamento Administrativo Nacional de Estadística” ((DANE), 2020), carried out an analysis in which an index of vulnerability to COVID-19 considering demographic characteristics such as age and population density, as well as their previous health conditions. Fig. 13 illustrates this indicator.

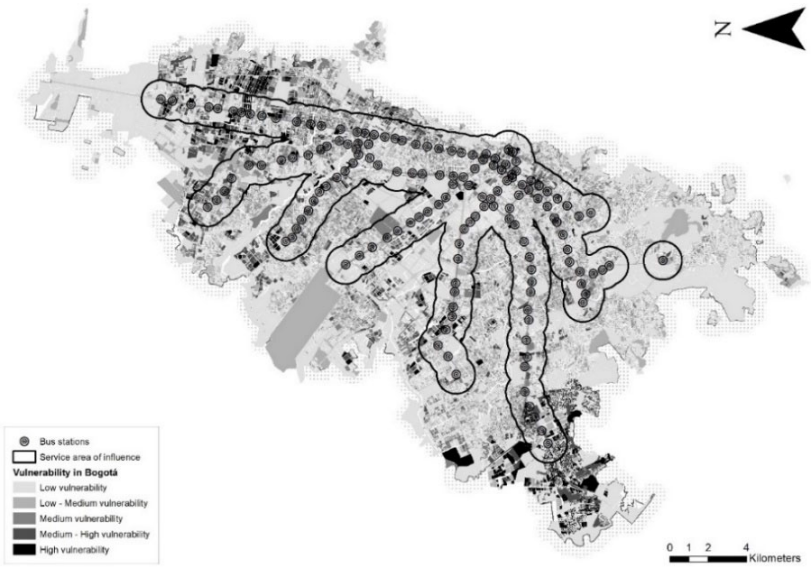

Figure 13: Vulnerability to COVID 19. Source: Own elaboration based on data from ((DANE), 2020)

Based on the previous study, it was possible to know the risk that the main users of the BRT have. The analysis using ArcGIS included the population that is 1km away or the so-called last mile and consisted of identifying the level of vulnerability our users are in the highest proportion. As shown in the following table, the highest proportion of vulnerability is found in the range of low and medium-low vulnerability with 41% and 36% respectively.

Vulnerability category	Percentage
Low vulnerability	41%
Medium - Low vulnerability	36%
Medium vulnerability	15%
Medium - High vulnerability	5%
High vulnerability	2%

Table 3: Vulnerability proportion

Vulnerability could be a factor that explains people's behavior related to the interaction with public transport. People would probably use more public transport if their risk perception due to the vulnerability of their home was low, and if they did not coexist with relatives with previous health conditions.

5.3 A brief graphical analysis

We are going to present some descriptive analysis of statistics, that can be explained by the influence of political decisions (which work as restrictions to people's behavior). The first one of them is Fig. 14, a graph that relates the percentage of decrease in the demand of both, BRT and on board validation bus service, with the COVID-19 cases identified, by the date in which the results of the tests were given. The focus of the analysis will be the two waves of cases that can be identified, particularly bnentetween July 11th/2020 to August 28th/2020 and from December 14th/2020 and January 31st/2021, and the time after they took place.

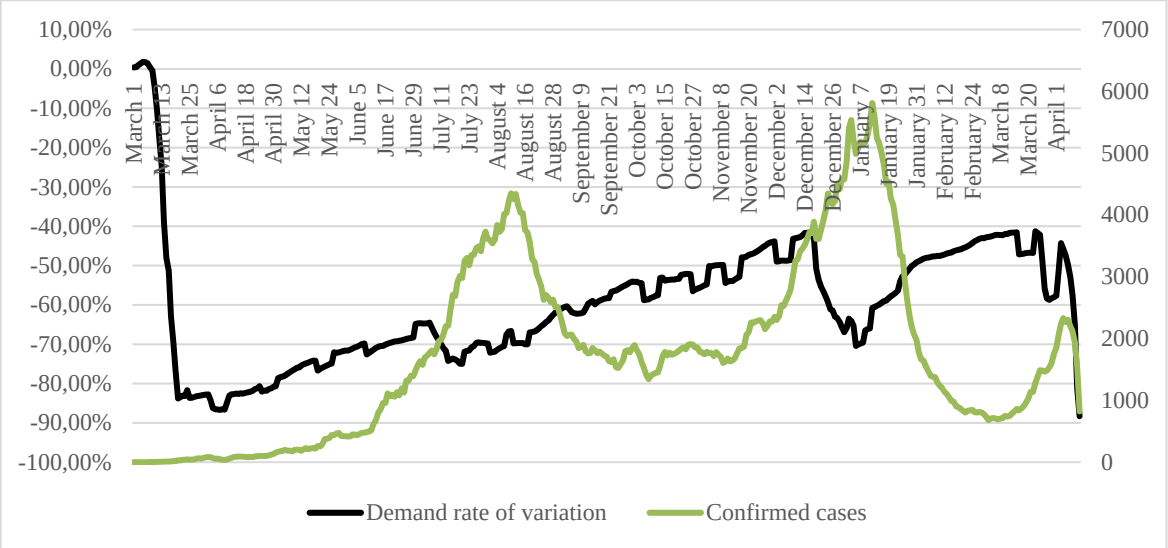

Figure 14: Change in the demand and cases by diagnose date

On the first interval, it is observed that, as the cases start to rise, the administration takes restrictive measures to prevent the effective contacts between people. This reflects in the transport system as a strong decline on the daily demand. Then, the demand of the system starts growing slowly, while cases continue increasing. After that, the ticket validations keep growing even when the diagnosed cases start dropping. Once the wave passed, the demand of the system continued to grow in a quicker way, but the number of confirmed cases kept stable during most of the “valley” observed.

On the second interval, the pattern is similar. The growth of cases can be observed since November 21st, day in which the anniversary of the national strike was commemorated. This was followed by a decrease on the demand of the system since December 18th, not due to the policies chose by the administration anymore, but because of the Christmas celebrations. As the demand of the system decreased, reaching its lowest point on January 5th (which was the first day of the second cycle of localized confinements), the confirmed cases grew onto the peak of the second wave of the pandemic. When the cases started to decline, the demand was already growing. This can be evidence of the uncorrelatedness of COVID-19 cases with the use of public transport.

A counterargument can be that the effect of the confinements or the dropping of the demand can be lagged. One way in which this can be observed is by taking the cases by the date on which the first symptoms appeared. However, this data is incomplete in the Health Department (Secretaría Distrital de Salud - SDS) dashboard’s downloadable data because there are 203.211 (of 713.559, by April 9th/2021) observations without any date assigned. The tendencies described above do not change, as shown in Fig. 15 .

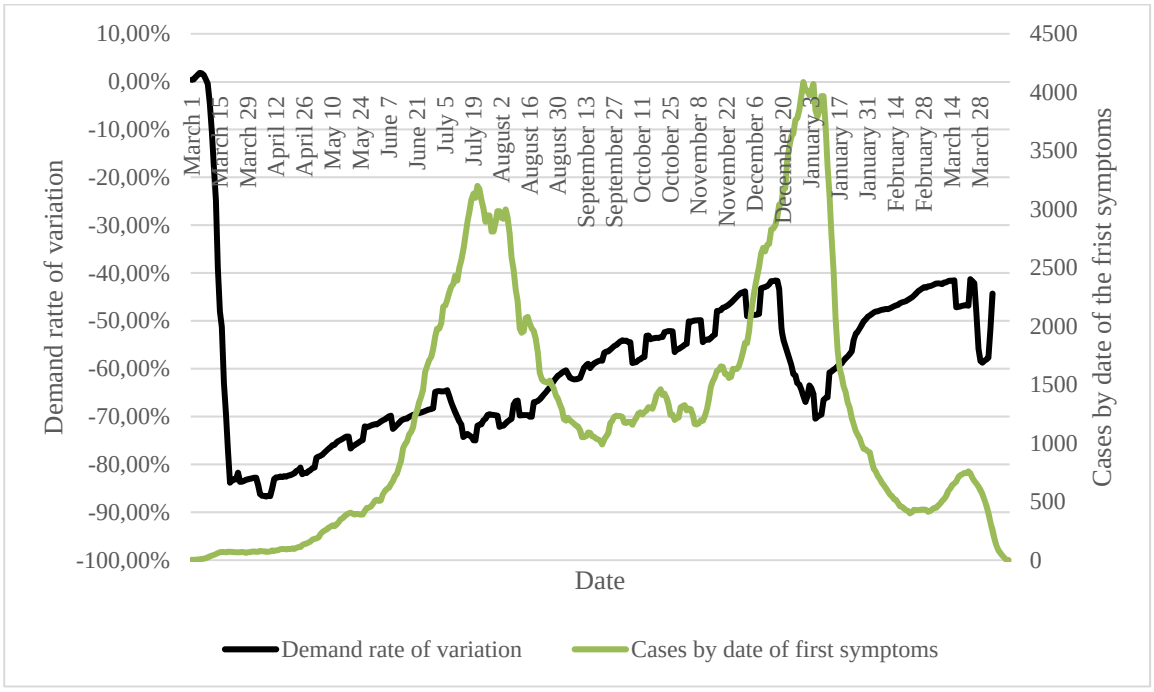

Figure 15: Change in the demand and daily confirmed case by date of symptoms

Furthermore, the decisions taken during the peak of the first contagion wave seem to coincide with the stabilization and start of decline of the cases, while, during the second wave, the new symptoms observed rose just as the demand of the public transport declined. An objection for the second analysis is that, on average, the symptoms start to appear some days after the contagion occurs. That can be answered with another indicator generated by the SDS: the effective reproduction number, which is calculated subtracting five days to the date in which the symptoms were initiated, with a time window that may vary through time. We use the latest boundary of the window. Fig. 16 illustrates this indicator:

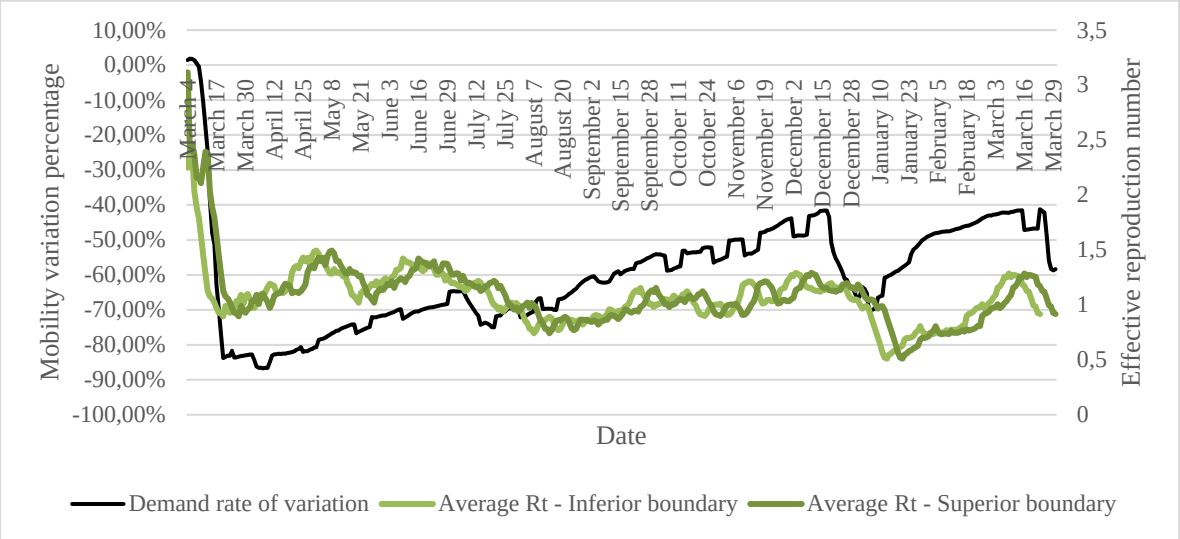

Figure 16: Daily effective reproduction number and demand rate of variation

The patterns do not reflect the behavior of each other. For example, after December 15th the demand drops two weeks earlier than the effective reproduction number or even three weeks superior boundary is used. The last figures indicate that the big changes in the relevant variables of the pandemic depend on factors that are different from the decisions taken with respect of the transport system. So, there is not a direct relationship between the evaluated variables and the contagion could be explained by other social interaction patterns, as well as by the natural behavior of the virus.

6. CONCLUSIONS AND POLICY LESSONS

The use of geographic information tools helps public transport systems to manage the demand variations, caused by the response to the state of the COVID - 19 pandemic, to make informed and focused decisions to prevent and mitigate the contagion on each of the areas of the city.

Analyzing the data of one year of the pandemic, during the time lapses when there was a progressive increase in demand for the TRANSMILENIO system, this slow growth does not

appear to have a direct relationship with the number of infections or the reproduction rate of COVID - 19.

It was possible to show that the policies of the decrees implemented in Bogotá are reflected in the changes in the demand of public transport which shows that most of the population effectively complies with social isolation and biosafety measures.

For the next research, this study suggests analyzing the possible causal or non-causal link between the contagion and the public transport system.

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