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KEY ASPECTS OF IT-SERVICES INTEGRATION IN INTELLIGENT  
TRANSPORTATION SYSTEMS OF MEDIUM-SIZED CITIES: AN EXPLORATORY  
QUALITATIVE STUDY

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# Key aspects of IT-services integration in intelligent transportation systems of medium-sized cities: An exploratory qualitative study

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## Abstract

Many cities, in developing countries, do not have an effective and efficient urban public passenger-transportation system (UPPTS). Likewise, given the concentration of cities and the increase in the mobility needs of their inhabitants, in the last decade, some proposals have emerged for the integration of information technology (IT) services in UPPTSs. These proposals aimed to improve the provision of UPPTSs and to seek sustainable mobility in medium-sized cities. To achieve this, it is important to recognize the key aspects of IT-services and technology integration that provide functional improvements in the UPPTSs of these populations. This research conducted an exploratory qualitative study to identify which aspects influence the design and implementation of technology-integration projects, in UPPTSs, in medium-sized cities, in developing countries. The information analyzed was collected through interviews and observations made with decision makers of the UPPTSs studied. The results obtained show the requirements and prioritizations that each UPPTS aims to achieve with IT support. Based on this, the key categories for IT-services integration, in UPPTS, in medium-sized cities, were defined. These key categories play an important role in the phase prior to the implementation of technology in UPPTSs.

**Keywords:** Information Technology; Public Transportation; Interviews; Intelligent Transportation Systems; Functional Requirements; IT Services

## 1. Introduction

*Urban public passenger-transportation systems* (UPPTSs) influence the infrastructure and economy of cities. UPPTSs are shared by most citizens and directly affect their well-being [1]. Public transportation, in a city, responds (i) to changes in the mobility patterns of its inhabitants, (ii) to the increase in transportation options, (iii) to vehicular congestion, and (iv) to the environmental effects occasioned by the automobile fleet [2].

Faced with the concentration of population in cities and the increasing mobility needs of citizens, *intelligent transportation systems* (ITSs), for passengers, contribute to improve the environment and the life quality in cities [3]. As an example, the medium-sized city of Piraeus, in Greece, had a population of 200,000 and faced

heavy traffic congestion. This problem has been reduced with the implementation of intelligent traffic-light control systems, reducing traffic jams by 20% to 50%, depending on the time of day analyzed; travel times by 8% to 12%; and air pollution by 10% to 17% [4]. Additionally, to ensure mobility and infrastructure, Piraeus provided various means of public transportation such as electric shuttle buses and small electric cars to drive specific routes around the downtown area or visit designated access points [5].

Despite the success of Piraeus, in many cities, in developing countries, an effective and efficient UPPTS is far from being a reality. This is the case of India, where different means of transport, in medium-sized cities and towns, correspond to informal means that compete to supply the mobility needs and demands of the population [6]. Likewise, in Colombia, the use of private vehicles has increased to the detriment of UPPTSs, with an annual increase of 14.7% in motorcycles and 6.6% in automobiles [7]. The Colombian city of Montería, Córdoba reflects the consequences of the high use of motorcycles for individual trips: (i) increase of emissions; (ii) increase of informal transportation; (iii) negative impacts on the use of public transportation and road safety [8].

In the last decade, several proposals, aimed to improve UPPTSs and sustainable mobility, have emerged in Latin American countries; especially, in the UPPTS of Colombian, Peruvian, Panamanian, Argentinean, and Brazilian medium-sized cities [9]. These proposals approach from reforms with the formulation of specific policies to improve mobility in developing countries [10], to the integration of technological systems to meet the needs and generate good added value to Latin American cities [11]. One of these proposals is the design of *Strategic Public Transportation Systems* (SETPs, in Spanish), which consist of the restructuring of UPPTS, in Colombia's medium-sized cities, to improve service provision through the adaptation of road infrastructure and the implementation of *information technology* (IT) based solutions [12,13]. The purpose of SETPs is to achieve safe, integrated, efficient, accessible, and sustainable mobility, while integrating IT services based on ITSs [14].

Despite the praiseworthy goals of SETPs, of the eight SETPs prioritized and co-financed by Colombia, only a few cities have started their commercial operation, with the following two causes of delays: (i) delays in the construction of the required road infrastructure, with an advance of 46% of the total kilometers completed [15]; (ii) the acquisition of the necessary information systems to control the fleet, deliver information to the user and collect fare payments [13]. Additionally, during 2020, occupancy capacity, in UPPTSs, was limited to 35% due to the COVID-19 pandemic, adding the confinement of people and the fear of contagion, in UPPTSs, as new barriers that generated economic losses for this sector [16].

Therefore, it is important to recognize the key aspects in technology and IT-services integration that offer a functional improvement to UPPTSs, in medium-sized cities. In this research, an exploratory qualitative study was conducted to identify the key aspects that should be considered to design and execute technological-integration projects for the UPPTSs. The case study analyzed was the implementation of SETP in Colombia.

The data analyzed for this study were collected through interviews and observations made to SETP decision makers, delving into the technological needs present in these systems. The results obtained in this research are associated with

previous works focused on the mobility of the medium-sized cities studied, such as (i) solutions such as the automatic detection of traffic infractions [17,18], (ii) the evaluation of public transportation drivers [19] and (iii) the identification of low-cost computer systems to optimize the performance of UPPTSs [20].

This article first presents a literature review, followed by a complete description of the research methodology. After, the main findings are presented in the core of the document: the categories that define the key aspects for the integration of IT-services, in UPPTSs, in Colombia. Following, data coding is presented showing the progress from the raw data to the aggregated theoretical categories. Finally, the study is summarized in the concluding discussions and conclusions, and future work is presented.

## **2. Literature review**

A *transportation system* is defined as a physical entity for the mobility of people and the movement of goods from an origin to a destination. The entity is formed by infrastructure, transportation means, facilities, and ways of organization of their use [21]. In turn, public transportation differs from other transportation systems in the supply of both utilities (infrastructure and/or vehicles) and scheduled services for several hours per day and several hours per year [22].

*Intelligent transportation systems* (ITS) are systems applied in transportation environments to improve the driving experience and the safety of drivers, passengers, and pedestrians. These systems can contribute to the labor, energy, environmental and economic efficiency of transportation systems [23]. Several authors define ITS as the application of modern technologies in sensors, computing, and communications with the aim to improve the efficiency, safety, and sustainability of ground transportation [24,25] without the need to increase the capacity of the road infrastructure in conventional transportation networks [26]. Featured services offered by ITSs include vehicle data capture, highway data capture, electronic transport fare collection, traffic management systems, emergency vehicle preference, and road condition monitoring [27].

In the last decade, ITSs have evolved to leverage technology and services from other industries (open-source software, enterprise software, IT services) [28]. In this sense, it is important to differentiate the concept of ITS applications and/or services from the notion of ITS technologies. Applications describe the functional part of the system, while technologies are the resources (hardware, software, and tools) needed to implement the system. An ITS service can be delivered with high-cost advanced technology but can also be implemented with low-cost technologies fulfilling the same functionalities [29]. Therefore, an ITS service possesses a low-cost approach when its cost falls below the willingness to pay of customers (authorities, end users) and its application affects both developing and developed countries, due to the necessity to reduce public spending, which includes the investment and operating costs over the entire life cycle of these services [28]. This approach becomes even more relevant today, when the world economy is shifting from a goods-based model to one of value, employment, and economic wealth creation dependent on services [30].

The level of IT integration, in the context of public-transportation services, has been evidenced in applications such as electronic booking, trip planning and for

obtaining real-time service utilization information. Transportation systems –in cities such as Bogotá, Buenos Aires, Curitiba, Mexico City, and Rio de Janeiro– have mobile applications that provide the previously mentioned services [2]. The inclusion of technologies to achieve advanced transportation systems, in the city of Ilorin, in Nigeria, has demonstrated operational efficiency in the areas of vehicle scheduling and trip booking, reduction of waiting times, user assistance, and comprehensive historical recording of bookings, trips, and others [31]. The above examples show the opportunity to improve public-transportation service delivery using ITS, which requires a strong commitment from all stakeholders, in the public-transportation sector, and employing reference frameworks to implement these technologies such as the *Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT)* [32].

For medium-sized cities, in Colombia, the criteria with the greatest influence on transportation-mode selection for users are walking time and waiting time [33]. In this regard, research has been developed to design technological solutions to improve service provision in UPPTSs. From these works, arose proposals oriented to the design of ITS services under reference frameworks [25,34] and to develop low-cost onboard devices for the vehicular fleet [35,36]. Other works proposed the use of neural networks for the intelligent control of traffic light systems [37] and the promotion of the daily use of non-motorized transportation modes (e.g., public bicycle systems) [38].

### **3. Methodology**

The methodological application of this work was based on two aspects. First, the literature review presented above, which required a search for previous research related to intelligent transportation and public transportation systems in medium-sized cities. Second, the empirical results of an exploratory qualitative study conducted in eight (8) medium-sized cities of Colombia, with the participation of the Chief Operating Officers (COO) and Chief Technology Officers (CTO) of the government companies that are implementing the Strategic Public Transportation Systems in Colombian medium-sized cities.

#### *3.1. Research approach*

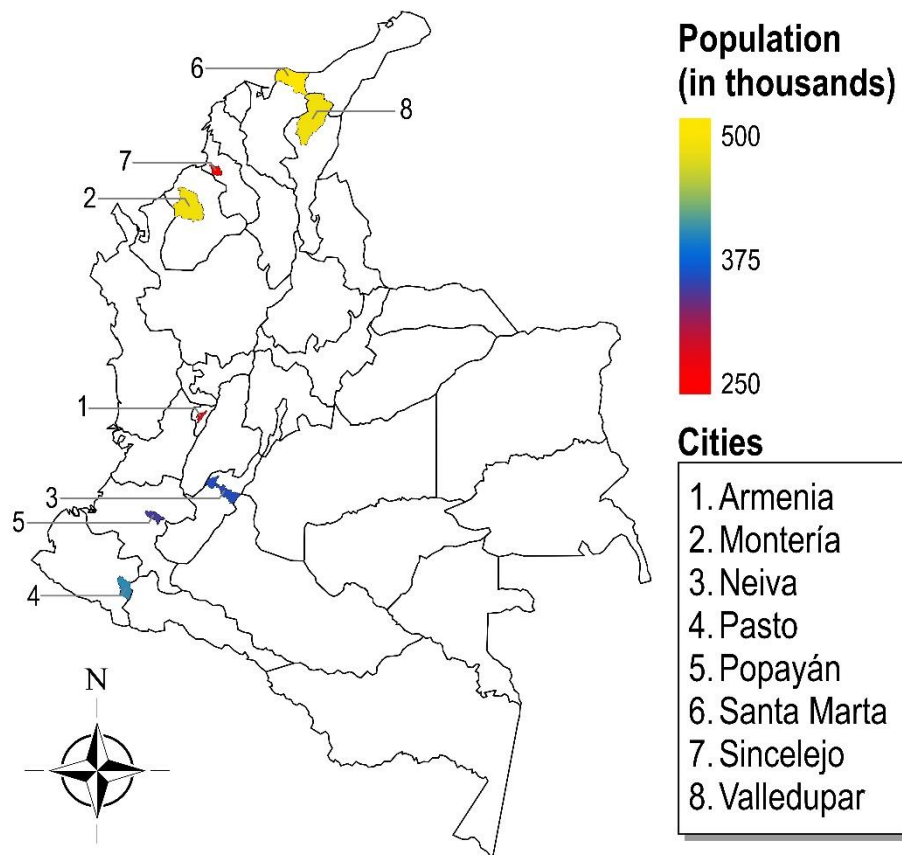
The process of this research was defined as a qualitative study. This type of study can be defined as any research that produces findings that cannot be reached using statistical procedures or any other method of quantification [39]. From this perspective, it is possible to address research on organizational performance, social and cultural phenomena, and interactions between populations. This is the case of public transportation, as an important sector within the dynamics of a city.

Data in this research were obtained by means of semi-structured interviews, an effective method to capture interviewees' explicit comprehension of a phenomenon [40]. In this type of interview, participants receive very similar stimuli, and it does not involve a unique sequence for all interviewees [41]. This was done with the aim to identify notions and relationships in the raw data, and then organize them into an explanatory theoretical scheme [39]. Similarly, a sampling of events representative of significant theoretical abstractions was carried out, using semi-structured interviews as instruments to obtain information. These interviews were then

compared with each other, in the search for properties and dimensions, considering the range or variation in the dimension as the main factor.

### 3.2. Participants

In Colombia, there are 12 medium-sized cities with the capacity to implement a SETP. Currently, eight (8) of these cities are in the system-implementation phase, while the remaining four (4) are in the design and financial resource allocation phase of the project [42]. In this study, the former eight cities were considered. Figure 1 shows the geographic location of the medium-sized cities under study, which have a SETP system. The color scale indicates the number of inhabitants in each of these cities.



**Figure 1.** Colombian medium-sized cities that are in the system-implementation phase of a SETP.

This research focused on a discriminate sampling that included a total of nine (9) interviews with the COO or CTO of UPPTS companies, in Colombian medium-sized cities. Of the nine interviews conducted, eight interviews were conducted with officials of cities where a SETP is being implemented. The ninth interview was conducted with the operator of one of Colombia's Integrated Mass Transportation

Systems (SITM<sup>1</sup>, in Spanish), which is a Latin American benchmark for innovation and best practices in public passenger transportation [7]. A total of 16 officials were interviewed in the sessions, who together represented a total of 9 different public-transportation companies. Table 1 summarizes the demographic information about the 16 participants.

**Table 1.** Demographic information of participants.

Characteristics (n=16)	n	%
<b>Position</b>		
Chief Operating Officer (COO)	7	43.7
Operations Assistant (OA)	4	25.0
Chief Technology Officer (CTO)	3	18.8
Others*	2	12.5
	<b>M (SD)</b>	<b>S (K)</b>
<b>Experience (in years)</b>	6.2 (4.7)	1.8 (4.4)

M = Mean, SD = Standard Deviation, S = Skewness, K = Kurtosis.

\* This item includes planning and R&D managers

### 3.3. Interview procedure

Because of the pandemic caused by COVID-19, the stages of this research were conducted under the measures of confinement and social distancing. Online qualitative research through video interviews, network focus groups, documentary searches on the web and in digital databases, requires techniques that facilitate the work without requiring physical face-to-face interaction. The use of digital media, in multiple daily facets, leads researchers to understand that they are facing a new research era [43].

Therefore, the interviews were conducted via videoconferencing using the *Microsoft Teams* of the *Office 365 suite*. Emphasis was placed on the information provided by the officials interviewed in the virtual sessions. In these sessions, semi-structured interviews were conducted, each lasting approximately 60 to 80 minutes. The interview guide consisted of sixteen (16) baseline questions (provided in Appendix A), which were developed based on concepts derived from the literature, preliminary work, and following the interview design process to obtain the desired information [39,44,45]. Also, six (6) complementary questions, based on a Likert scale [46], were conducted to identify the prioritizations established by each city regarding the integration of IT services in public transportation. The interviews were recorded on video with the consent of each participant.

### 3.4. Data coding

Interview recordings were transcribed verbatim by research assistants, each transcript with a length between 11 and 16 single-spaced pages. The transcripts were analyzed using qualitative content analysis due to the specific but exploratory

<sup>1</sup> A *SITM* is the organized combination of infrastructure and equipment in a system that covers a high volume of passengers and responds to a significant percentage of mobilization needs in a defined area of influence.

nature of this work. The data were structured by selective coding through logic-driven discriminate sampling. In this sampling it is important to have a certain degree of consistency since the comparisons were made systematically in each category. Data collection is guided by information analysis. This analysis is performed in parallel to data sampling. The aim of selective coding was to incorporate and refine the categories to create a larger theoretical schema, using story argument writing as an analytical technique [39].

### *3.5. Discriminate sampling and data validation*

Discriminate sampling consists of a highly selective choice where the researcher chooses documents, people and sites that increase the comparative analysis opportunities. This process may involve revisiting sites, documents, or people, or explore new sources to get the data needed to saturate the categories and conclude the study. [39].

Both the COOs and CTOs interviewed had an average of more than five years of experience in the transportation sector, are high-ranking officials within the government companies, and are the decision-makers on the planning, adoption and use of technologies, and implementation of standards in public transportation in medium-sized cities.

The comparative analysis was made by contrasting the information obtained during the interviews with the information provided by the SITM operating company, and with national studies associated with UPPTS [10,13,33]. The answers given by the different interviewees to the sixteen basic questions were compared with each other and with the validation information. The data were validated, simultaneously, at each step of the sampling and analysis, with additions or modifications being applied as new data came into the investigation. In this way, the interpretations made were affirmed or denied. Only concepts that meet all requirements of the rigorous comparison process became part of the theory. Discriminate sampling ended when the categories obtained from the analyzed data were saturated.

### *3.6. Categorization*

Categorization is the process of labeling or classifying data units, which is performed during the coding process. The essence of categorization is to identify a unit of data as pertaining to, representative of, or exemplifying some more general phenomenon [47].

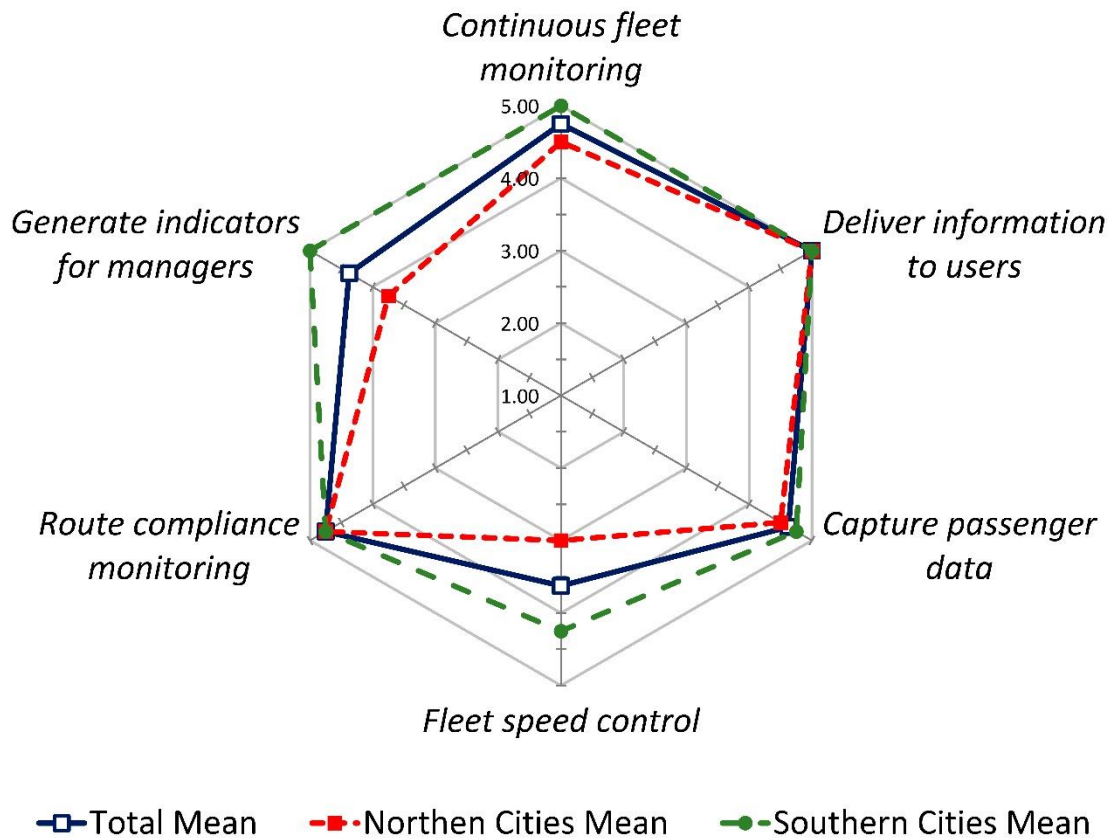
After many concepts were compiled in the discriminate sampling, the categories that define the most significant influential aspects that should be considered to integrate IT-services in UPPTS were established. These aspects can contribute to improving the operational processes of transportation systems in Colombia's medium-sized cities, making them more competent and sustainable. The categories resulting from this research are presented in the next section of this article as subsections.

## **4. Results**

Results of this study are divided into technological, economic, and administrative aspects.



Figure 3 shows the functions associated with public transportation in medium-sized cities that can be strengthened through IT integration. These functionalities are shown according to the relevance established by the interviewees considering the needs of their cities. The graph indicates a scale of 1 to 5 for each item shown, where 1 is not very relevant and 5 is very relevant.



**Figure 3.** Relevance of functionalities associated with IT integration in public transportation in Colombian medium-sized cities.

The results show that all the cities studied homogeneously prioritize the adoption of technology for the delivery information to users, the drivers' route compliance, and the capture of passenger data. On the contrary, during the processing of the information obtained during the interviews, it was found that functionalities such as continuous fleet monitoring, generation of indicators for city administrators, and vehicle speed control show heterogeneity in technological adoption. While the four medium-sized cities located in the south of the country (Armenia, Neiva, Pasto, Pasto, Popayán) assign a high relevance to these elements, the four medium-sized cities located in the north of the country (Valledupar, Santa Marta, Sincelejo, Montería) indicated that these elements have little relevance in their technological integration strategies. This divergence may be caused by cultural differences between the citizens and institutions of both regions, the lack of resources for the

execution of works, the economy of each city, and the size of their transportation systems [33,38,48,49].

Finally, about fleet speed control, one of the interviewees expressed the following comments:

*“Today we are having commercial speeds of 16 km/h. This is because there are a lot of informal vendors, there are a lot of obstacles on the road that limit the speed, so it increases up to 19 km/h in commercial speed, so it is not so important [to control it] ... because as I know the city, I know it is not so significant”.*

With the information provided by the officials interviewed, the functional requirements that IT must address in UPPTSs of Colombia's medium-sized cities are described. All the COOs of the SETPs interviewed indicated that the functionalities that IT should cover are the following: fleet scheduling; vehicle location and traceability; data storage in the cloud; interoperability with other information systems. In addition, seven of the officials interviewed expressed that other functionality to be covered are: visualization and control of data in the operations center; passenger counting; panic button and incident management. The functionalities mentioned above were contrasted with the validation information, and the relevance of their implementation through IT was found. In this regard, one of the experts interviewed expressed the following:

*“When [the vehicle] is already on the road, I have to guarantee the control of the interval [between vehicles]. Then, I must have constant monitoring of where the vehicle is, and for that I must mount all the onboard equipment in the vehicle, and I must have all the equipment on the ground to guarantee that reliability... Then I must have a very reliable onboard system, which cannot be altered by the driver, resistant to vibrations, and a very good communications network to get that information to the ground”.*

#### *4.2. Economic aspect: investment and cost of the technology*

Technology integration projects in UPPTSs, in medium-sized cities, require large capital investments in both the acquisition and operation of computer and IT systems. In the context of ITSs, technology implementation projects involve operation and maintenance (O&M) costs that correspond to 40-55% of the total budgeted investment [11].

To integrate IT services in UPPTSs, the life cycle of the technologies to be selected must be considered, considering the level of maturity, the complexity of O&M, replacement, and final disposal of technological equipment. In this regard, the COOs and CTOs interviewed affirmed that the computer systems of their UPPTSs should use technologies based on open standards. One of the general comments, expressed by officials, in this category, highlights that *“the technologies to be acquired must work with open communication protocols, be configurable for each city, be interoperable, and be low-cost”.*

Considering the low-cost technology approach expressed by the SETP officials interviewed, one of the concerns that arose is the relationship between the quality of

the technology and its cost. In this regard, the COOs and CTOs stated that they require technological solutions for their UPPTSs that they can afford, that are low-cost, but not the cheapest on the market, since the technologies to be acquired must meet the quality requirements demanded by legislation and international standards. When contrasting this requirement with the validation information, one of the experts interviewed expressed the following:

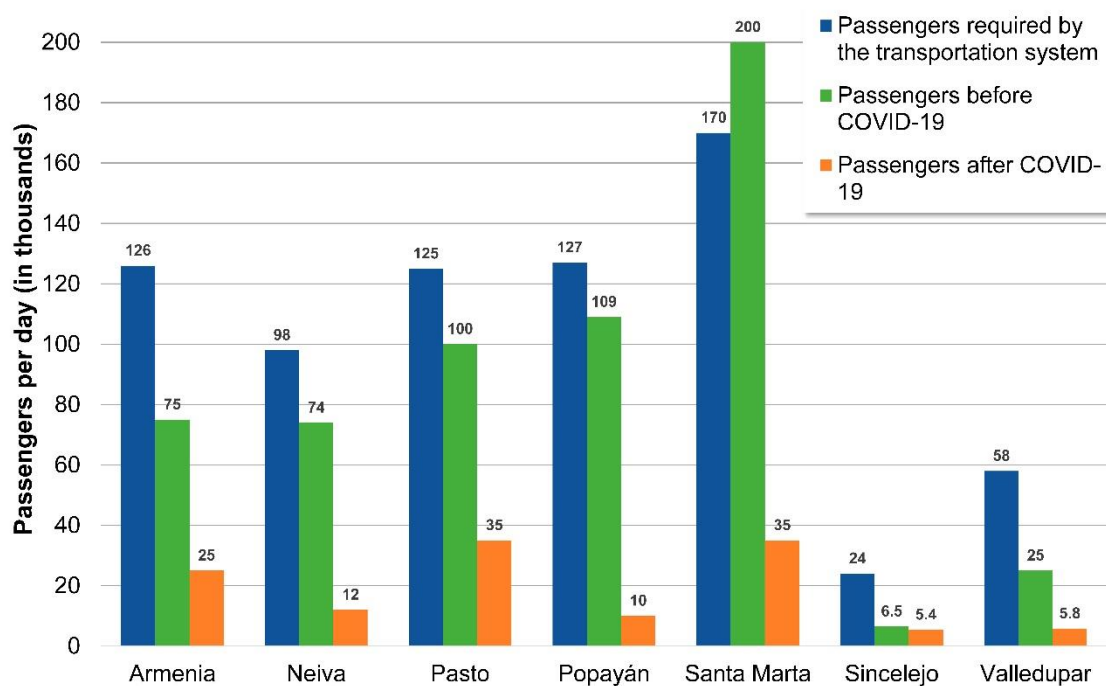
*“You have to look at the cost at which the technology guarantees me that the environment where I am going to mount it, in the vehicle, will withstand it. Yes, they can be inexpensive, but they must have the necessary resistance for the use I am expecting... There is low-cost equipment that is very good, but that low cost has a reasonable point, because, in some cases, the cheapest equipment does not meet all the quality attributes”.*

Currently, there are low-cost IT alternatives for UPPTSs that can meet the desired requirements for public transportation in the medium-sized cities studied. Proposals such as the use of smartphones and mobile applications for vehicle and user data capture [20,50,51], the use of information collected by vehicle sensors through the *onboard diagnostic* (OBD) interface [20,28], and the use of low-power, wide-area open communications networks [36,52], are examples of technological solutions with a low-cost approach that can supply the IT requirements, in UPPTSs, in medium-sized cities for a SETP.

#### *4.3. Administrative aspect: current challenges and technology decisions*

UPPTSs, in Colombian medium-sized cities, faces major challenges related to the decrease in the number of users and the increase in illegal transportation, both of which threaten the sustainability of transportation systems. To this is added the effects caused by the COVID-19 pandemic, limiting the number of passengers that can enter the system to maintain social distance. The general results of the *Urban Passenger Transportation Survey* conducted by the *National Administrative Department of Statistics* (DANE, in Spanish) of Colombia show that, during the first quarter of 2021, the number of passengers transported by public transportation systems had a decrease of 34.2% compared to the first quarter of 2020 [53].

Figure 4 shows the number of passengers required by the transportation systems of seven of the cities under study, as well as the number of passengers transported before and after the onset of the COVID-19 emergency. Except for one city, note that the number of users transported by UPPTs, in medium-sized cities, is less than the number required by the system to sustain its commercial operation without economic limitations.



Data provided by SETPs in November 2020

**Figure 4.** Number of passengers transported by public transportation systems in Colombian medium-sized cities.

Faced with financial challenges due to the lack of public transportation users, municipal governments provide resources to the system through fare stabilization funds. The officials interviewed stated that this strategy seeks to maintain the sustainability of the public transportation system, while encouraging more users to join the system. In this regard, one of the COOs commented that, in his city, the following is happening:

*“With the current demand conditions [of the system], the project does not close financially yet, since the tariff that should be charged for the use of transportation should be double what it is set today. Therefore, the tariff stabilization fund is being contemplated to be able to make that contribution that is necessary to cover the operation [of the system]”.*

To attract and maintain more passenger demand for transportation, it is necessary to implement better quality and comfort attributes in the UPPTSs [54] of the cities interviewed. These attributes include: the availability of WiFi networks in stations; mobile applications to reduce waiting times; innovative ticketing systems; competitive fees through new financing models for operating costs; among others [55]. In this scenario, one of the SITM experts interviewed said that:

*“We must begin to differentiate revenues, because [the transportation system] cannot continue to live only on user fees... The company has the goal that non-fare revenues, such as advertising and commercial space, reach 15% in the*

*coming years. Today we are at 12%, but that is the call to all transportation companies, they cannot live only on user fees”.*

From an administrative point of view, the COOs and CTOs interviewed stated that the integration of IT services, in their UPPTSs, should help capture new users and mitigate the impacts produced by illegal transportation. This can be achieved by following the proposals provided by studies conducted in Latin America, which generate practical recommendations on technologies for urban transportation and public-private operation schemes, to generate added value to Latin American cities [56].

## **5. Discussion**

This article provided an empirical experimental approach, with the participation of 16 officials (COO, CTO, and others), from the eight medium-sized cities that correspond to all the municipalities implementing a SETP in Colombia. It has been found the requirements and prioritizations that each public transportation system wishes to achieve with IT support. Particularly, by taking an orientation towards inference procedures with connections between the empirical and theoretical domains [47] and employing a series of general theories, a group of conceptual variables that can be measured empirically was recognized. Based on this, key categories have been identified and defined for the integration of IT-services, in UPPTSs, in Colombian medium-sized cities.

In the *technological aspect*, it was found the needs that the UPPTSs of the analyzed cities aim to implement with the support of information technologies. This category raises questions related to the level of technology required by these cities, whether the identified needs can be met by implementing mature technologies, emerging technologies, or technologies that do not yet exist [56]. The concepts expressed by the interviewees indicate that the services prioritized for implementation can be implemented with existing technologies that have a high degree of maturity (e.g., Driver Monitoring Systems, Automotive Real-Time Data Analytics) and technologies with high expectations in the medium future (e.g., Mobility as a Service, 5G Networks, Blockchain, Internet of Things) [57], which can meet the functional requirements desired by SETPs.

The *economic aspect* shows the low-cost approach desired by the cities studied for their UPPTSs. This is an approach based on the services offered to public transportation users rather than an approach based purely on technology, which is only there to support the service [28]. The concepts that saturate this category show the need to implement technical systems that SETP investors can afford and that meet the quality requirements demanded by current legislation. Interviewees expressed strong interest in technologies based on both open source and open standardized network protocols as options to integrate technology solutions into their transportation systems. This perspective presents an advantage over the use of closed technologies generally offered by suppliers, who create a monopoly over the system and impose unfavorable conditions for scalability, maintenance, and replacement of the technology [11]; as an example is the use of LoRa technology for data transmission in UPPTSs, which works in a cost-free unlicensed spectrum, in

contrast to Sigfox, which offers longer communication range but has subscription costs for the service [58].

The *administrative aspect* shows what decision makers of the transportation systems studied have contemplated to face common challenges, such as: to increase the number of passengers mobilized by the system, to reduce the supply of illegal transportation, and to recover the economic losses caused by the COVID-19 pandemic. Interviewees emphasized on improving the quality of service by adding value through improving the user's comfort and experience when interacting with the system [11,59].

There is a contrast between the prioritizations established by the cities in the north of the country (Valledupar, Santa Marta, Sincelejo, Montería) and the decisions prioritized by the cities in the south of the country (Armenia, Neiva, Popayán, Pasto), as shown in Figure 2. This contrast may have its origin in the economic, social, and environmental differences of the populations [60], in addition to the high dependence of some of these cities on public resources [61]. The mentioned contrast between cities, according to their geographic location, is an observable trend related to the capacity of municipal authorities, in medium-sized cities –in Latin American countries such as Argentina, Bolivia, Brazil, Colombia, Chile, Ecuador, and Peru– to respond to the needs of the inhabitants by managing technical, administrative, and financial resources for decision making related to local collective welfare [62].

Finally, during the design and development of this study was addressed the search for categories related to environmental and social aspects [37,54,63] in the analyzed public transportation systems. However, no findings that saturate these categories were found in the interviews. Several interviewees made inferences in these two categories when expressing their answers to the questions, stating that positive results will be achieved for these through the categories described above (technological, economic, administrative).

## **6. Conclusions and recommendations**

This research identified the key aspects that should be considered when integrating IT-services, in UPPTSs, in medium-sized cities. During the interviews conducted, it was found a great interest on the part of the officials interviewed to improve UPPTSs, in the case study cities, with the help of cutting-edge technological solutions. In such solutions, technological, economic, and administrative aspects play an important role in the study phase prior to the implementation of IT-services aimed to deliver information to users, route compliance, and data capture of users and vehicles.

Improved service delivery through the integration of IT-services can encourage (i) greater use of public transportation, (ii) increase the number of users transported per day, and (iii) achieve the sustainability goals established for each system. With the results obtained in this research, it is possible to present recommendations on technologies and IT-services to complete the implementation of the eight UPPTSs analyzed in their respective cities, and in other medium-sized cities of similar characteristics at national and international level. It is important to consider the existing differences between the prioritizations of the technological aspect in the cities studied and their relationship with their geographical location (north/south) because including social and economic characteristics of the population can guide the design of suitable strategies for IT-services integration in public transportation.

These recommendations may also be applied to plan the integration of IT services of the four Colombian cities that are designing their strategic transportation systems, and to other medium-sized cities in other developing countries.

For the next stages of this research, it is recommended to conduct interviews with officials of the transportation systems studied with questions oriented to the integration of O&M policies, to identify technologies that can improve both areas of the system. Similarly, for future research, it is suggested that a comparative analysis be made with similar transportation systems located in other regions, such that the sample of medium-sized cities studied be expanded to include a significant number of populations worldwide, and that quantitative analysis techniques can be included to explore common patterns that favor IT-services integration in UPPTSs, in medium-sized cities, in developing countries, around the world.

### **CRedit authorship contribution statement**

**Tomas Ramirez-Guerrero:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing - Original draft. **Mauricio Toro:** Conceptualization, Formal analysis, Funding acquisition, Project administration, Resources, Supervision, Writing - Review and editing.

### **Declaration of Competing Interest:**

None.

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### **Appendix A. Structure of the interview guide**

Table A.1 contains the interview guide used during the sessions with the Chief Operating Officers and Chief Technology Officers interviewed. Sections 1, 2 and 3 correspond to the 16 core questions of this study.

**Table A1.** Interview guide

<b>Section</b>	<b>Questions</b>
1. Introductory questions: Exploration about the profile of the participants	Would you tell me about yourself? What has your experience been like as a SETP [position] in your city?

2. System operation: Exploring specific details on operational aspects.
- Are you familiar with Intelligent Transportation Systems?
- How are they integrating ITS services to SETP, specifically in fleet management?
- What are the necessary requirements for the fleet management system for SETP?
- How efficient should the fleet management system for SETPs be?
- As an *Ente Gestor*, are you looking for a fleet management system that you can afford? You can expand your answer.
- What is the breakeven point between the operation and the number of users entering the system? How have you calculated it?
- How do you secure funding sources for the system to maintain the operation and management of the fleets?
- How soon do you expect the system to be fully operational? What strategies are you implementing to accelerate the process?
3. Technology resources: Exploring specific details about the technology required by the system.
- What are the sources of information and how should the information flow in the fleet management system?
- Do you think there is a need for custom-designed fleet management technology solutions for SETPs? Why?
- Which technologies have you studied for SETP fleet management? Which have you selected?
- Do you think that the quality of the technology to be acquired is related to its price?
- What do you think of low-cost vehicle tracking systems?
- How are you applying international standards for technology integration in fleet management?
4. Complementary closed questions: Estimating the relevance of functional requirements.
- From 1 to 5, being 5 the highest, indicate the relevance of the following approaches:
- Continuous monitoring of the vehicles during their route
  - Provide the user with information about the routes provided, arrival times, frequencies, etc.
  - Obtain information on passengers in the vehicle, entry and exit of the passengers.
  - Monitoring the speed of fleets.
  - Control compliance with the routes assigned to vehicles and unauthorized stops.
  - Provide managers with statistical information on the use and compliance of the system.

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