The RFID technology to improve productivity in the public transport and the quality of services to passengers

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Abstract: In many cities, the agencies that make the public passenger transport management are still struggling to plan and develop services to improve the mobility of people. Are difficulties that stems from a lack of updated surveys to collect information on the displacement characteristics of people to do out their activities in urban areas, by means of public transport. The main reason is that these studies are complex to perform and involve high cost. Technological convergence, understood as the ability of different network platforms to carry different types of services, allows the public transport, with the current trend of resource management, an increasingly immediate action in the operation. In this article, a proposal to use radio frequency identification (RFID), together with other technologies of intelligent transport systems (ITS), can produce the resources to remedy the deficiencies. It uses components of the RFID into smart cards used to pay the fare as source of information. Automatically acquire data to construct matrices origin-destination and other important information about the condition in which services are offered and can help planners and managers to do programmed services more efficiently, improving the passengers experience.

Keywords: Public transport, Radio Frequency Identification (RFID), Transport surveys, Operational control, Matrices origin-destination and Transportation planning.

I - INTRODUCTION

The effects generated by population density, economic growth and indiscriminate use of natural resources **[6]**, pressured the governments of cities to build public policies and make investments that aims to maintain or improve the support structures the quality of life of the inhabitants without, however, prejudicing the functioning of their economic activities **[45]**. Among the priorities, public transport stands out **[26]**, because it have plans to democratize people mobility **[46]**, the operation of productive structures **[16]** and environmental sustainability of cities **[23], [41]**.

It has significant economic and social role **[22]**, because it becomes essential to the quality of life for people who need to move to the opportunities that the cities offer **[47]**. Transportation services are critical to the economy, as they allow the operation of the productive sectors and provide the conditions for consumer goods and services **[8]**.

The greater efficiency of public transport service, allows positive impact on cities and it provides the quality of life of its citizens, because collaborates to reduce congestion, pollution, energy consumption, indiscriminate use of fuels and harmonizes the use of road infrastructure **[36]**.

Moreover, inefficient transport services affects with tangible costs, people and cities leading to increased consumption of fuel, vehicle wear, saturate infrastructure and amplify cost of labor, which, added to other factors, are resulting in increased the rates of service and directly impacts in value of money (inflation) **[1]**. In some of these cities, observed increased accident rates, traffic deaths and problems related to air pollution **[2], [13]**, **[15]** and **[43]**.

The importance of transport in daily life of people is evidenced by more time spent in commuting between the place of residence and activities involved (work, play, study, etc.). Also, generates intangible costs, especially those related to increases in times of connection shifts, long waiting times and all this cause discomforts that affects people's views about the transport as a public service by interfering directly in the everyday lives in the cities **[42]**.

To do evolution of the transport network and diminish or extinguish problems, it is necessary to dedicate efforts to do perform maintenance on this network and its services, based on policies that seek sustainability in cities. To perform these tasks, many municipalities delegates the management, to public agencies to do plans, supervise and remunerate the services of public transport in order to reach your goals.

However, despite the efforts of agencies and suppliers, user expectation for the quality of transport services always tends to increase in their level of requirements due that he want evermore to have travel more faster and with greater comfort and safety **[19]**. The constant attraction of these people for public transport, in fact, requires a creative attitude of public and private bidders, to develop alternatives that they can compete with competing modes, especially for dealing with problems that routinely plague the functioning of cities (traffic, consumption of energy, pollution, accidents, etc.).

One of the main challenges that agencies face in creative planning in the transport sector is to form an expanded knowledge base about the problems, so that they can decide on how to improve and make more efficient the services.

The expanded knowledge base, with regard to analyzing the collection of information, comes from recorded facts arising from everyday data collection. This step is critical to planning activities due the knowledge provided **[43]**. However, to obtain data, more broadly, faces technical problems, financial and operational and not always, them guarantee the quality of information **[4]**. With these justifications, planning public transport systems in many cities are directions to a technocratic treatment, which makes undifferentiated actions to passengers, relegating to the background the user's actual needs **[25]**.

This article presents a proposal to use RFID (Radio Frequency Identification) for obtain data to assist in the construction of new and important information about the behavior of passengers in the use of public transport. This information is relevant to do the activities of the bus operation management and make plans in the transport network.

In the proposal, RFID technology components will be are installed on buses and in smart cards used by passengers to pay the fare. The cards carried by passengers enables identifications when they get close to a bus, and while performing your trip. Finally, no longer recognized when the passenger move away from the vehicle after disembarkation. The events corresponding to these facts will be recorded through a computer system.

The innovation offered by technology RFID in the public passenger transport sector is to do real time measures of capacity occupied of bus by passengers while running the shuttle service and identify the locations of origins (embarkation) and destinations (disembarkation) of the passengers. The activities focused on the analysis of demand, from this information, will be able to expand the knowledge base needed to act immediately to solve problems, develop adjustment plans (short-term) and evolution of the network (medium and long term). Moreover, there is an expectation that the use of RFID may replace manual surveys with advantages, as decreased cost and significantly increase the ability to collect and register new facts and make an assessment on services, uninterrupted.

II – Difficulties to do plans in short term

To accommodate the increased demand and the travel concentration at certain times is authorized by agencies new schedules in the services to fit the capacity of supply **[17]**. Generally, these updates can be performing to existing routes, adding or reducing offer (capacity) **[7]**.

Because it is a finite system, the transport resources have limits to grow in capacity and availability. Currently, in many cases, does not let further increase. They are restrictions that bring, ultimately, inefficiency in updating the program of services and leads to degradation of the level of quality, increasing hence the passenger dissatisfaction **[29]**.

In transport networks with interconnected services, have more integration and increased travel training (networked) by users **[3]**. These features promote different patterns in the passenger's behavior in discrete travel, with little or no connection between services **[17]**.

In activities to plan, the services to support chained trips cannot consider merely the demand per hour and the capacity of the buses as the only variables to set the standard offer of services. Before, one must also consider the passenger displacement profiles determining even the regions that concentrate origins and destinations of trips [33] and identifying the points of articulation of the road public transport network (natural connections).

If agencies can monitor changes in demand over the routes and adjust their buses, the quality of service can be improved and become more attractive. Besides knowing the details of the offer (distances, needs and time) and availability of infrastructure (roads, terminals, stations, etc.), it is necessary to know better, and systematically, the characteristics of demands for public services (number of people, destinations of trips, times and places of concentrations, etc.) **[29]**.

Generally, information like this, are considered in the transport modeling plans with long-term horizons, but ignored in the short-term adjustments. However, are short-term adjustments that retains the capacity and frequency of transport services, to do improve public opinion on the functioning of the city and save time for passengers for produce activities and consume product and service.

This is what happens in the city of São Paulo in Brazil. With an annual growth rate of 0.76%, the city has 12 million inhabitants and a population density (population / area) of 74.58% **[32]**. It appears as the economic center of the country and is the most populous city. To support urban mobility of people, the city has a public transport network (subway, train and bus) that was been consolidated over the years. The public transportation services has been administered by the city through the São Paulo Transport - SPTrans, a company contracted to carry out the management of all the 1,300 bus lines in the city. Sixteen consortia made up of private companies and cooperatives, are responsible for operation of 15 thousand buses. These buses do 190,000 daily trips totaling 3.7 million km, carrying 9.5 million of people **[10]**.

III – Intelligent Transport System (ITS) Applications

Intelligent transport systems (ITS) describe technology applied to transport and infrastructure and uses resources of information and communication technology, with sensors, navigation and data processing to do managing the operation of transport systems and rationalize the use of road infrastructure, increase security, provides greater accessibility, reduce travel times, reduce costs and reduce negative environmental impacts **[18]**, **[34]**. Overall, the ITS should promote an intelligent link between transport systems and services users of this system **[49]**. ITS can be applied in every transport mode (road, rail, air, water) and services can be used by both passenger and freight transport. Since 2004, São Paulo city has benefited from intelligent transport systems to monitor public transport operations. All buses are equipped with AVL equipment - Automatic Vehicle Location and equipment for electronic billing (AFC - Automatic Fare Collection). Points of stops in exclusive lanes are interconnected by fiber optic network, the terminals and embarkation and disembarkation areas equipped with camera systems, variable message panels and monitor that display information about the services of bus. The shuttle service also provides a System of Electronic Ticketing - SBE, which records high usage rate of smart cards, named here of "*Bilhetes Únicos*". Around 94% of trips are pays with these cards **[9]**.

The use of Intelligent Transportation Systems, allowed real-time information, and began represent an important role in helping agencies and supplier companies make critical decisions quickly and efficiently. Through automated systems, significant amount of data can now be collected and treated by high-performance computing systems that help transportation engineers and planners to do their job more efficiently **[24]**.

IV – Data Acquisition on Characteristics of Passenger Demand

Information on travel demand characteristics are obtained through manual searches, especially those that use direct methods **[28]**. This type of research involves large amount of data from large samples, and registered by interviewers (people, equipment or forms) and supplied by the respondents. The searches are done by researchers through research per household census **[35]** or direct approach **[40]**. Also used indirect research counts, without interviewers, the latter being widely used in the transportation sectors **[27]**.

The researches require great deal of preparation and demands high expenditure of human resources, money and time **[10]**. However, due to reduction of resources, the research actual limits not provides the coverage and the timing needed to adequately understanding the characteristics of people's movements. In São Paulo, with intervals every ten years, are conducted household surveys interviewing 3% of the resident population **[30]**. These surveys given rise to matrices origin-destination (OD) which use to be source of information to plan the public transport network of the city. However, despite their importance, they are complex to do **[29]** and entail high expenditure of time and money.

Indirect methods of research, particularly the human observation, are being replaced by ITS. More and more cities have within transportation system, CCTV cameras, electronic tracking and equipment for the electronic payment **[5]**. These systems bring advantages for passenger transportation and management systems. Uninterruptedly data collected produces huge amount of useful information for analysis of the population, with notable advantage when compared to manual processes of data collection.

The matrices O / D produces information crucial to the planning stages of the transport network. The identification of locations of sources and destinations of trips and concentrations have been helping to solve many engineering problems. Arranged in arrays O / D, the information allow enlightening vision of how happens the search for people by city sites **[20]**.

Once collected, the data provided by embedded electronic systems aid to do programs with great ability of supply and represents advantages to solve problems. However, the data collected by these systems do not grants directly know the detailed characteristics of passenger movements through the origins of the local record and destinations of trips. Alternatively, studies based on these data are need to obtain estimates, but that are approximate references. It is necessary effort to integrate the data provided by the automatic positioning systems (AVL) with data of electronic transactions (AFC) through smart cards and validators. The company public SPTrans already performs this type of data integration and analysis in São Paulo.

However, there are still problems that end up making that kind of information, not yet reliable. The main one is the accuracy in identifying locations where the landings took place, representing the destinations of passenger movements. In São Paulo, the buses have, following the boarding space, a hall that accommodates multiple seats for people with reduced mobility, elderly and pregnant women, which are arrange on the front of the vehicle before the validator. Thus, a passenger needs to cross this hall to get to that validator. When they reach the validator equipment inside the bus, then approaches smart card and the service are payed. This event is register into identification card, while the passenger may have embarked several meters before. Situations where the departure hall is crowded with other passengers or the own decision passengers to travel in this salon and only cross the validator nearing the end of your trip, are not uncommon. These behaviors generate data that are record by electronic systems, but they produce incorrect information about origins.

The difficulty is that the electronic equipment installed in the buses records only data that infers the locations of the origins of travel, but do not produce data on the locations of destinations. In systems, which control access only at the entrance (open systems), some assumptions must be made to infer the landing location (destination) passenger: the passenger is destined for station where your next trip starts; the passenger finishes his last trip of the day in the location where he started the first trip of the day **[52]**.

Managers of São Paulo transport system think of adopting electronic systems for measuring the capacity of vehicles. APC systems (Automatic Passenger Counter). These systems operate by means of sensors that are place on doors of buses, and counts the amount of people that pass. However, these systems do not help to determine the places of origin or destination of passengers.

In this scenario, despite the significant volume of data collected electronically by ITS, it is not possible to obtain accurately the places where embarking and disembarking passengers, unless, are used data processing and application of models, allowing estimates. Even with all this effort, the information generated may still have error levels that could compromise the evaluation.

V – The RFID technology

The RFID technology has been widely discussed by companies, technical community and scholars on the subject and there are extensive amount of material related to your description, development and application **[38]**. It has the advantage of storing information on what is being identified and transmit this information to compatible requesters via wireless network without the need for physical contact **[37]**, because it allows components of the technology applied to objects, products or people, may be recognized at distance through the issuance of radio frequency waves **[12]**, **[31]**.

The RFID devices have integrated circuits for modulating and demodulating radio waves, converting the reflected waves into digital information. Its main components: a coil (antenna) and a miniaturized chip arranged in self-adhesive labels or small objects of plastic or glass; equipment controllers of antennas that control signals emission; and computer systems (middleware) to select, handle and forward collected data to the company management systems **[39]**.

RFID technology was first develop in 1948, but it not built for commercial applications until years 80. One of its first applications known during World War when it was use by the British radar system to differentiate between German planes and their own aircraft. After that, with its development, it has become relevant within the industry sectors, trade, services and government. It has been used in a variety of applications **[21]** such as control of the supply chain (logistics), product tracking (schedules control), authentication (quality control), access control (security), anti-theft systems (security), documentation and identification of persons (passports and ID patients in hospital), electronic payment (smart card and road tolls) and smartphones (NFC).

Ensuring the functioning of RFID technology efficiently and safely still faces difficulties it has caused some resistance in its expansion in various industries. They are technological challenges to overcome data integrity-related issues and information security. The acceptance of global standards, patent domain, the infrastructure challenges, related to cost and return expectations on investment - ROI, integration with enterprise systems and personal privacy, are themes that stand out **[51]**.

VI – PROPOSAL, METHODOLOGY, AND TEST RESULTS IN RFID USE.

The methodology is to build processes to examine the application of RFID technology in the public transport sector, objectively to collect data to inform about the number of passengers inside the bus (capacity) and, together with geolocation devices (GPS), identify places of origin and destination the travels. All experiments were following by the company of public transport in the city of São Paulo, *São Paulo Transporte S.A.* and had the collaboration of technology companies.

The methodology used was to perform tests with people carrying smart cards with RFID devices on the bus, simulating real situations and monitor results. For this, the following work steps built:

1. Identify a tag whose performance was adequate for the purpose of testing, i.e., operating near the human body and environments with many metal parts;
2. Examine if the passenger habits that keep their smart cards in bags, pieces of clothing, in the middle of books, etc., hinder the identification of the TAG;
3. Encapsulate the RFID components in smart plastic cards;
4. Configuration a program RFID into reader equipment to collect data;
5. Equip bus with RFID reader and integrate it to AVL for obtained geographic position data from GPS;
6. Test, through practical experiments, automatically monitor the loading and unloading of passengers and else other operational information.

Stage 1:

The first step was to identify a function TAG with efficient performance when used near the human body and in environments with many physical elements such as on buses, which have several pieces of metal and variable number of passengers.

A bus was equipped with RFID devices. A reader was install and two antennas coupled, and were position near the area of the door. For this step, the antennas of circular polarization, were calibrated with + 30dBm power. In the Figure 1 show the position of the antennas, next to boarding gate.

Figure 1 - Antennas on the bus, positioned near the boarding door.

We assessed four sets of TAG, each with different designs and characteristics. One set contained the TAG (UECODE-7) with drawings of antennas that were develop especially as a prototype for the experiment, on the condition to be the best operation when close to the liquid. Each set consisted of five similar TAG. Five volunteers were ask to develop the test and each given a TAG of the same model. As a procedure, each volunteer was position to three meters from the bus, he walked to the boarding door, boarded the buses passing between the antennas and walked to the validator of the vehicle and then, disembark, returning to the starting position.

All events recognized by the writer conveys an EPC number (Electronic Product Code). The reading TAG was follow by a notebook computer connected to the equipment.

With a similar procedure, four TAG sets were examine. The results are show in Table 1 below:

STEP 1 - TESTS IN THE BUS - ENERGIZING TAGS						+30dBm - 2 Antennas Antenna 2 near the wind glass	TAG on volunteer hand
TAG	5 DIGIT FINAL EPC	READINGS (RECORDS)	TIME (SECONDS)	RECORDS/ SECONDS	TOTAL RECORDS	METHOD	OBSERVATION
UCODE7 AD235	22201	9	15	0,600	28	Enter, go to validator - return	OK
	22202	8	14	0,571			OK
	22203	7	22	0,318			OK
	22204	8	18	0,444			OK
	22205	7	12	0,583			OK
UCODE7 AD370	33301	6	9	0,667	26	Enter, go to validator - return	OK
	33302	4	7	0,571			OK
	33303	5	16	0,313			OK
	33304	5	15	0,333			OK
	33305	6	14	0,429			OK
Sirit - RSI654	55501	10	16	0,625	57	Enter, go to validator - return	OK
	55502	9	13	0,692			OK
	55503	15	17	0,882			OK
	55504	11	15	0,733			OK
	55505	12	16	0,750			OK
UCODE7 - Proto	77701	14	13	1,077	65	Enter, go to validator - return	OK
	77702	12	14	0,857			OK
	77703	16	15	1,067			OK
	77704	10	9	1,111			OK
	77705	13	14	0,929			OK

Table 1: Test 1 - Verification of EPC TAG. Source: SPTrans.

All TAG were energize and transmitted data to the reader device. However, the TAG UCODE7 / PROTO (Figure 2) stood out, due obtain the highest number of recorded events.

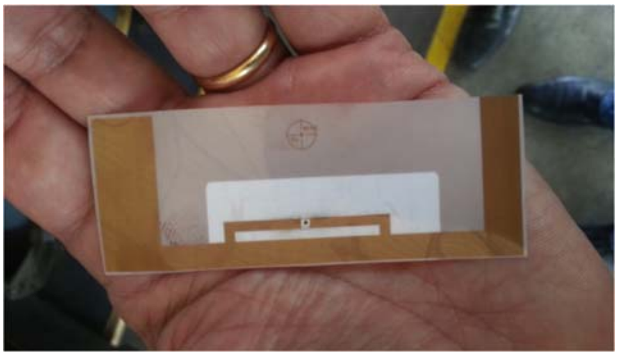


Figure 2 - Prototype (TAG-UCODE7) used in the experiment.

Stage 2:

The second step of the test aimed to verify, among the different models of TAG, which would present better performance, measured by the number of readings per second when users hide the TAG. Each volunteer hide the TAG in a location of your clothing (pants or shirt pocket) or within objects (bags, wallets, books, etc.) simulating behaviors of passengers.

All volunteers did test procedures, as occurred in the previous step. The results shown in Table 2 below:

STEP 2 - TAGS HIDDEN INSIDE DRESS OR OBJECTS (Simulating behaviour of passengers on the bus)							+30dBm - 2 Antennas Antenna 2 near the wind glass	TAG on volunteer hand
TAG	5 DIGIT FINAL EPC	TAG LOCAL IN THE BODY	READINGS (RECORDS)	TIME (SECONDS)	RECORDS/ SECONDS	TOTAL RECORDS	METHOD	OBSERVATION
UCODE7 AD235	22201	Shirt Pocket	9	15	0,600	28	Enter, go to validator - return	
	22202	Left front trousers pocket	6	15	0,400			
	22203	Inside wallet in the bag, cell phone in front of	6	22	0,273			
	22204	Behind the Badge, shirt pocket, cell	2	15	0,133			
	22205	Left back trousers pocket	5	13	0,385			from antenna 1
UCODE7 AD370	33301	Shirt Pocket	4	2	2,000	14	Enter, go to validator - return	Only 1 reading from antenna
	33302	Left front trousers pocket	2	1	2,000			Only getting in the bus
	33303	Inside wallet in the bag, cell phone in front of	2	15	0,133			
	33304	Behind the Badge, shirt pocket, cell	No records at all					
	33305	Left back trousers pocket	6	12	0,500			Only 1 reading getting in the bus
Sirit - RSI654	55501	Shirt Pocket	8	16	0,500	39	Enter, go to validator - return	
	55502	Left front trousers pocket	7	13	0,538			
	55503	Inside wallet in the bag, cell phone in front of	14	16	0,875			
	55504	Behind the Badge, shirt pocket, cell	7	15	0,467			
	55505	Left back trousers pocket	3	11	0,273			
UCODE7 - Proto	77701	Shirt Pocket	11	15	0,733	47	Enter, go to validator - return	
	77702	Left front trousers pocket	8	13	0,615			
	77703	Inside wallet in the bag, cell phone in front of	14	16	0,875			Read 5 m from door out the bus
	77704	Behind the Badge, shirt pocket, cell	5	3	1,667			Read only getting in the bus
	77705	Left back trousers pocket	9	13	0,692			when leaving the bus

Table 2: Test 2 - Verification of TAG when hidden in the clothing or objects of users. Source: SPTrans.

Although satisfactory for the sample, the results show that there are variations for data captured by the reader, and this fact depends on the greater exposure of the TAG in RF wave emitted by antennas. Table 3 shows the results obtained at this stage of the tests.

TAG	tag readings (L)	time (T)	T/L	time to 10 readings	amount of tag readings every 10 seconds
AD235	28	80	3,6	28,6	3,5
AD370	14	30	2,6	21,4	4,667
RSI654	39	71	2,2	18,2	5,493
PROTO	47	58	1,2	12,3	8,103

Time (T): seconds

Table 3 - Comparison of results between TAG.

The best results were achieve by prototype, which was 46% faster for transmitting data to the RFID readers, and 74% more identifiers than the average of the other three. From these results, the TAG UECODE7-PROTO has become exclusive for the next stage testing.

Stage 3:

In step 3, focused in the coexistence of radio frequency (RF) technology currently exists on the smart card to pay for the fare rate with the RFID technology coupled. The SPTrans Company invited representative's technology supplier of smart cards for testing and evaluating the solution where TAG-RFID should be incorporate into the smart card and be able to be recognized by reader devices within the bus.

In this process, the RFID tag was incorporate in smart cards, similar to those used by passengers to pay for the shipping rate. The microchip on the TAG (N-Bits transponder system, Read Only), received in his memory a unique sequence number that was associated with the UID (user identification) smart card, to be broadcast, at the time of activation by the reader . Thus, the captured records would be equivalent only to the card whose TAG transmitted it. The proposal provides for the structure of the card as shown in Figure 3, below.

Figure 3 - Smart card with RF technology currently in use and a proposed the hybrid smart card with components of RFID technology.

Following these features were produced 20 units of smart cards with the TAG UCODE 7-PROTO, that was approved the initial tests, to be used in the next steps of the solution. All cards have been identify, with sequential numbering, the UID and the EPC number. Figure 4 shows examples of smart card.

Figure 4 - Cards with RFID devices, manufactured specifically for this testing.

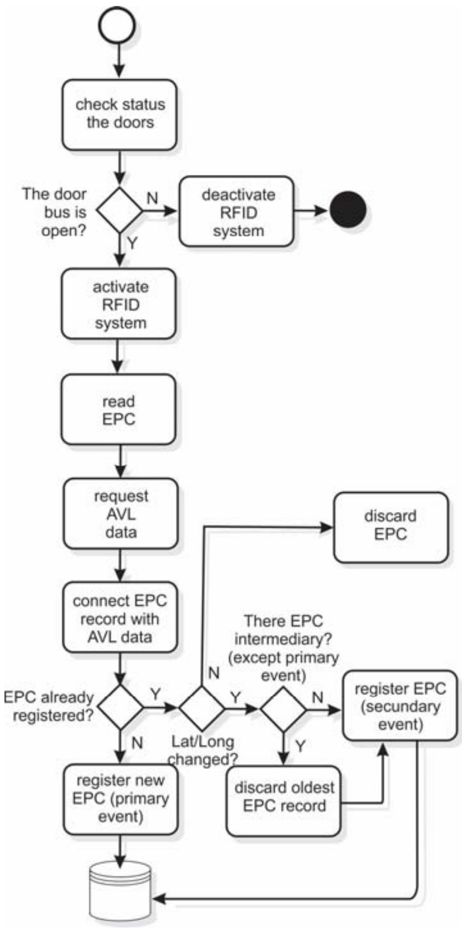
Stage 4

The step 4 was to prepare a reader equipment, scheduling functions so that he could recover the TAG EPC numbers on the cards.

Reader RFID with four antennas programmed considering:

- Filter events: only the record of the first and last event of a card will be used by the storage system;
- Ordering the data position Longitude / Latitude of the AVL system of buses GPS. It will Record the coordinate pair in the record of the TAG events at the time that collected the data. Add information about the date and time (HH: MM: SS) in the record;
- Program rule so that the reader becomes active only in the moment that, at least one bus door is open. When the doors are closed, the reader fails to collect data from TAG.

The rules were code in RFID reader, which contains a processor to perform the settings. In Flowchart 1, is represents the basic process of programming the device inserted.



Flow Chart 1: Process programmed into RFID reader.

To control the events, it developed a specific computer program, which allowed control interface the main features of operation of the equipment. Some features have been programmed so that the program simulate some conditions of the vehicle, such as opening or closing of doors and change of geographical location, functions that were useful for testing in the laboratory procedures programmed into the machine. Were also programmed, accountants whose results could be presented in a graphical interface, allowing monitoring the amount of shipments, landings and total passengers into the bus. In Figure 5 is show the program's user interface and main control functions.

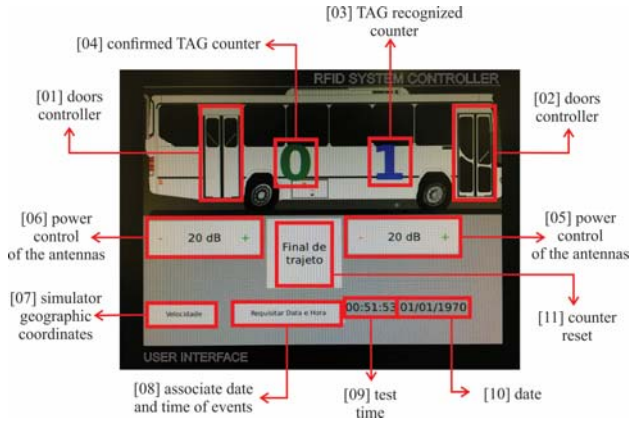


Figure 5: Program control interface

Stage 5:

In this step, a bus was equipped with a UHF RFID reader and where are positioned four antennas with circular polarization configured for 30dBm and + gain of 6dB in the vehicle interior. Two antennas in areas near the boarding door, where the flows embarking passenger on the bus occur. The other two antennas were install in the landing door area.

The antennas are offset one relative to the other, by 20 centimeters. From the point of view of who boards the bus, positioned to the left antenna, was installed to 1.20 meters from the bus floor, while the right antenna installed in 1,00 meter. Both were position with oriented main face to the area of shipping flows. On the back of the bus, near the disembark door, the antennas were misaligned following the same structure of the antennas that were fixed at front of bus. Procedures were performing to integrate the AVL and RFID UHF reader through CAN BUS door.

Stage 6:

The Step 6 was the RFID technology test run in the bus, and conjunction with ITS systems for information, perform the obtaining the number of embarkation, disembarkation and passenger inside the bus.

In this step, they participated 15 volunteers, each carrying a hybrid smart card. A number printed on a self-adhesive label that was affix to the clothing identified all volunteers. This number was associated with EPC number of the card and registered in a control sheet to manual monitoring. The volunteer was free to carry the smart card according your convenience, in the pockets of clothing, in wallets, bags or hand. At the stop bus, they stood up to 3 meters from the external of bus side and, one after the other, walked to the front door, boarded and passed between the antennae. Similarly, when authorized, landed through the back door, passing through the antennas installed in the area of exit.

To verify the correct obtaining geographic coordinates regarding events, the test was perform with a moving bus in a bus depot. Inside the garage they were designated five locations to represent stopping points and set a route for the bus. In Figure 6 shown an image with the locations of stop bus and the route to meet these points.

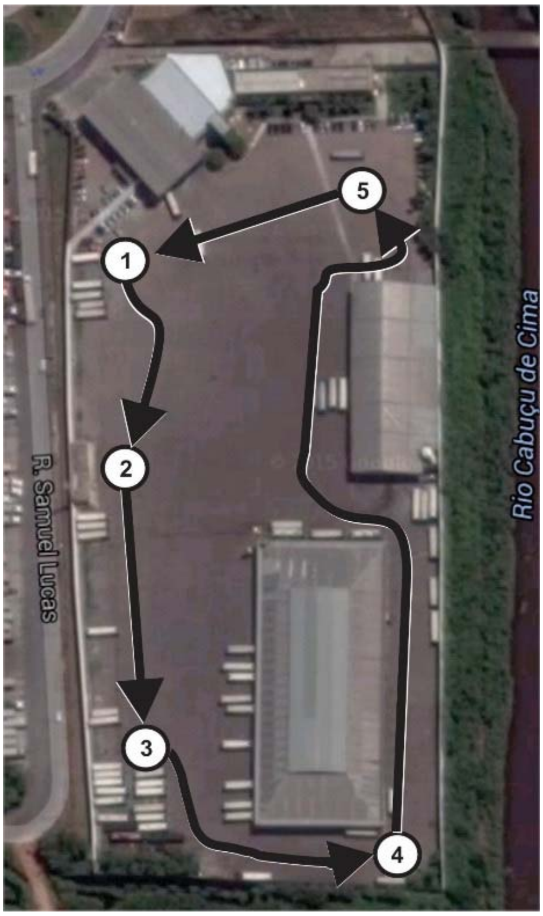


Figure 6 - Stopping Points and the bus route inside the garage to perform the tests - Source: custom of: <https://www.google.com.br/maps/search/-46,608374/@-23.4909017,-46.5616472,491m/data=!3m2!1e3!4b1?hl=pt-BR>

The test consisted in shifting the bus by itinerary to suit the five stopping points for seven straight laps, registering the EPCs, date, time and GPS coordinate.

Table 4 summarizes the results, comparing them between data recorded by the RFID system and data entered manually through observation.

	RFID		REAL			Volunteers
BUS	B	L	B	L	SB	on the bus
LAP 1	9	1	10	2	5	8
LAP 2	4	2	4	2	3	10
LAP 3	3	6	3	6	2	7
LAP 4	8	0	8	0	0	15
LAP 5	0	12	0	15	0	0
LAP 6	12	2	14	2	2	12
LAP 7	0	12	0	12	3	0

RFID: Data collected by RFID system
REAL: Data collected manually
B: Boarding the bus
L: Landing volunteers
SB: Volunteers who remain on the stop bus

Table 4 - Data recorded by the RFID system, recorded manually and amount of passengers on the bus in each lap.

The results showed that all registered events were properly associated with geographic coordinates and there was a passenger count inside the bus informing her cargo, and thus the test was considered satisfactory. However, some inconsistencies were observe, due to EPC reading errors of smart cards. They were realize 78 boarding of volunteers, however, the RFID system registered only 71 of them (91%).

OPERATIONAL INFORMATION:

The data stored by the RFID, allowed building the information about the operation. They were:

Matrix Origin-Destination:

Data were easily arranged in a matrix where they represented the places of origins and destinations of travel of passenger and amounts associated with these locations. Table 5 is a representation of the O / D matrix of travel of volunteers, conducted in the test.

matrix origin-destination (O-D)

O \ D	P1	P2	P3	P4	P5	total origins
P1	1	1			1	3
P2	3				1	4
P3	2		2			4
P4	2				2	4
P5						
total destinations	8	1	2	0	4	15

Pn: identification number of the bus stop point

Table 5: OD matrix obtained from data collected by the RFID system.

Travel time:

The total time of passengers travel considers the time spent since the time of the first embarkation in the bus, time while traveling, waiting intermediate time after the first disembarkation, and so on until the time the end of the trip occurred passenger. Table 6 are the results obtained from data collected in the test:

Volunteers number	8 final digit EPC	Travel time: time of the start journey	Travel time: time of the end trip	Travel time: Total travel time
1	EF559D16	14:17:49	15:46:18	1:28:29
2	CF169D16	14:17:54	15:41:22	1:23:28
3	6F6A9D16	14:17:57	15:38:49	1:20:52
4	AF129D16	14:19:06	15:38:50	1:19:44
5	CF3C9D16	14:19:11	15:33:30	1:14:19
6	EF979D16	14:19:16	15:38:53	1:19:37
7	0F8C9D16	14:32:14	15:07:28	0:35:14
8	4F9A9D16	14:21:56	15:43:28	1:21:32
9	CF299D16	14:21:59	15:43:26	1:21:27
10	2F6A9D16	14:34:58	15:07:39	0:32:41
11	6F909D16	14:48:59	15:38:45	0:49:46
12	AF299D16	14:24:14	15:38:42	1:14:28
13	8F589D16	14:24:20	15:46:54	1:22:34
14	8F909D16	14:37:35	15:38:33	1:00:58
15	0F7A9D16	14:37:58	15:46:42	1:08:44

Table 6: Total passenger travel time.

Total wait time of passenger at the bus stop point:

The waiting time wherein the volunteer stood waiting for the bus at the stop point was obtain by the difference in time between primary and secondary events of EPC records of the smart card. Table 7, shown is the sum of all waiting times of passengers.

WAITING TIMES IN STOP BUS

Volunteers number	8 final digit EPC	first connection: Stop bus	first connection: Waiting time	second connection: Stop bus	second connection: Waiting time	third connection: Stop bus	third connection: Waiting time	Total Waiting Time
1	EF559D16	P4	0:38:16	P5	0:15:26			0:53:42
2	CF169D16	P3	0:09:46	P2	0:12:28			0:22:14
3	6F6A9D16	P4	0:32:06	P4	0:13:33			0:45:39
4	AF129D16	P1	0:12:34					0:12:34
5	CF3C9D16	P5	0:10:03	P1	0:12:25			0:22:28
6	EF979D16	P5	0:10:05	P1	0:12:25			0:22:30
7	0F8C9D16	P4	0:12:10					0:12:10
8	4F9A9D16	P3	0:12:12					0:12:12
9	CF299D16	P3	0:12:58					0:12:58
10	2F6A9D16	P1						0:00:00
11	6F909D16	P3	0:12:15					0:12:15
12	AF299D16	P4	0:12:19	P3	0:12:43			0:25:02
13	8F589D16	P3	0:09:40	P4	0:13:31	P5	0:00:06	0:23:17
14	8F909D16	P4	0:10:54	P5	0:15:25			0:26:19
15	0F7A9D16	P4	0:10:30	P5	0:15:32			0:26:02

Table 7: Wait time passenger.

Renewal factor (RF):

The FR is crucial for calculate the capacity of buses. The passenger capacity of bus is predominant in defining the quality of service offered to passengers and measure the bus line efficiency. In São Paulo, the concession contracts and permission of services between the city government and operators companies delimits the maximum stocking rate of between 5 and 6 standing passengers per square meter. For obtain the capacity, the FR is a variable that is apply to the equation:

$$\textit{stocking rate on the bus} = \left[\frac{\left(\frac{\Sigma \text{passengers trip}}{\text{FR}}\right) - \Sigma\text{seat}}{\textit{usable area inside bus(square meters)}}\right]$$

In Table 8 presents the RF index obtained in every lap of the bus, evaluating their occupation in relation to embarkations and passenger landings.

CALCULATION OF RENEWAL FACTOR

Bus Lap	demand on the bus: P1	P2	P3	P4	P5	Passengers boardings	FR*
Lap 1	2	5	7	8	8	9	1,125
Lap 2	8	9	10	12	10	13	1,083
Lap 3	10	10	9	5	7	16	1,600
Lap 4	7	7	9	14	15	24	1,600
Lap 5	11	10	8	6	6	24	2,182
Lap 6	6	7	11	13	13	36	2,769
Lap 7	7	6	4	4	1	36	5,143
*FR = Renewal Factor						Line FR =	**2,400**

Table 8: Renewal Factor (FOR) obtained by RFID data.

Considering until the last trip (lap 7), the bus was carrying 36 passengers. To calculate the maximum amount of passengers on the bus just divide the total number of passengers boarding by FR line value:

$$\text{Passengers} = \left(\frac{36}{2{,}400}\right) = 15\ (\text{lap } 4, \text{P5})$$

VII - CONCLUSIONS

This article aims to start a discussion on the possibilities of obtaining important information with the application of radio frequency technology - RFID in urban public passenger transport sector and opens the prospect for future discussions on the portability of this smart card technology ordinarily used for payment of transportation.

We live in a stage of development characterized by the ability to obtain and share information instantly, from anywhere. The power of real-time information from the perspective of the manager and the transport provider enables application opportunities even more comprehensive and the use of public transportation technology infrastructure allows providing new services.

The adoption of an intelligent transport system (ITS), by integrating various technologies to monitor and improve urban mobility can become a decisive factor in the search for solutions that facilitate the daily life of the population.

The processing of data collected by technology devices results in crucial information so that planners can, through studies on passenger demand, update the operation of its transport systems, providing more precise adjustments to the schedules of buses, increasing the quality of services and evolving the conditions for the welfare of users.

The possibility of using RFID in the public transport sector based on vehicle tracking systems already deployed and running in several cities in the world and the popularization of smart cards for payment of the fare. Smart cards already commonly ported by users of public transport systems and thus configured as potential information providers. Add radio frequency identification components on these cards does not change the use for electronic payment of the fare and adds no user providence in its daily maintenance. However, its use allows data capture to provide indicators on time and places where moving users and vehicles in public transport.

Using RFID technology in smart cards to produce information that today are difficult and expensive to collect. This information should grant benefit in work supply management with increased focus on passenger demand with the following benefits:

- Automatized information about loading of passengers on the bus, and determine the maximum loading section. The section of maximum loading of a line is critical in determining the ability of the offer;
- Provide information to the user of the vehicle stocking condition. Allows determine the capacity of the vehicle, and, based on the results, tell users if the bus is empty or is crowed;
- Intervene in operation of vehicles to make it compatible forecast demand, controlling delays and advances. The control centers can provide extra vehicles in the case of identifying delays or concentrated passenger demand at certain points, improving services;
- Plans new services due to the persistence of information indicating changes in the use of the passengers profile;
- Plan new connections, obtained by the matrices of origin and destination (O / D) depicting the movements of passengers' journey;
- Identify connection points of trips where passengers do the integration of services.

Among the advantages arising from the use of technology in the transport sector, mainly in the activities of service management, are:

- Improve service according needs of people;
- Develop urban mobility plans which suit the growth and functioning of cities;
- Provide important information to assist users in deciding how and when to use the public transport services;
- Reduce the cost of managing avoiding the waste of human resources, financial and time in the development and implementation of manual searches;
- Become proactive management functions of the control centers on the operation of public service;
- Provide updated information to support the modeling of the transport network in the medium and long term;

Despite the fact that the tests were satisfactory, will need new studies where providers do effort of develop appropriate technology equipment for this type of application, with innovations in the design of antennas that are compatible to the layout of the bus, TAG more efficient to operate in this environment and system programming collect important data.

It innovation will help to make transport more sustainable, which means efficient, clean, safe and seamless. The expectation is that this type of initiative will enable significant advances in the management of transport systems, enabling not only improved quality but also perform better productivity.

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