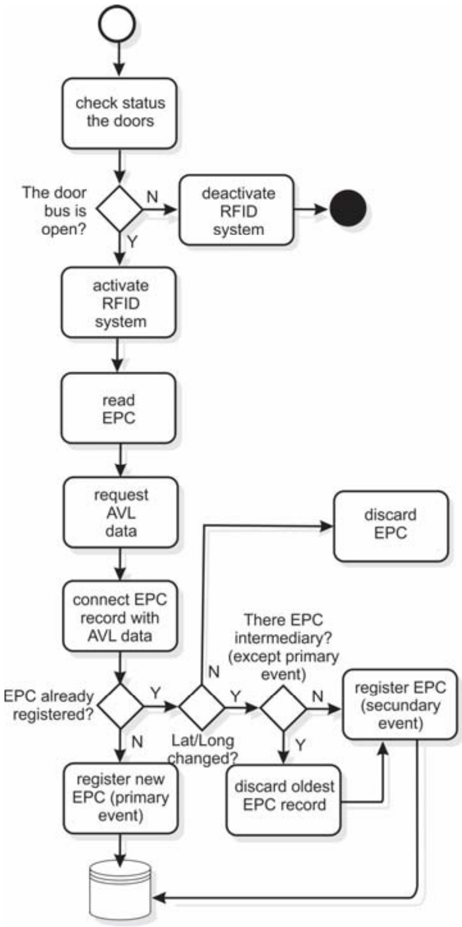

Flow Chart 1: Process programmed into RFID reader.

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.

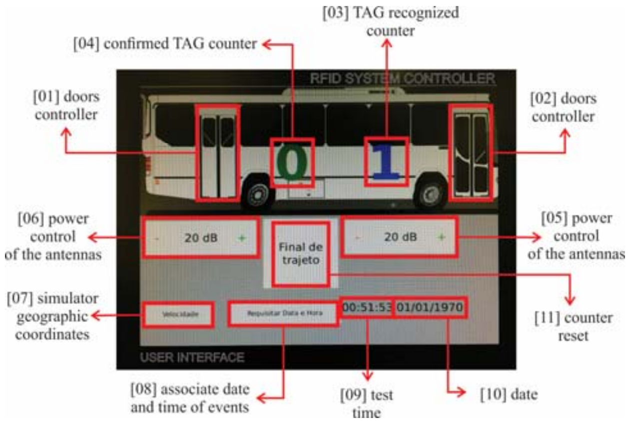

Figure 5: Program control interface

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.

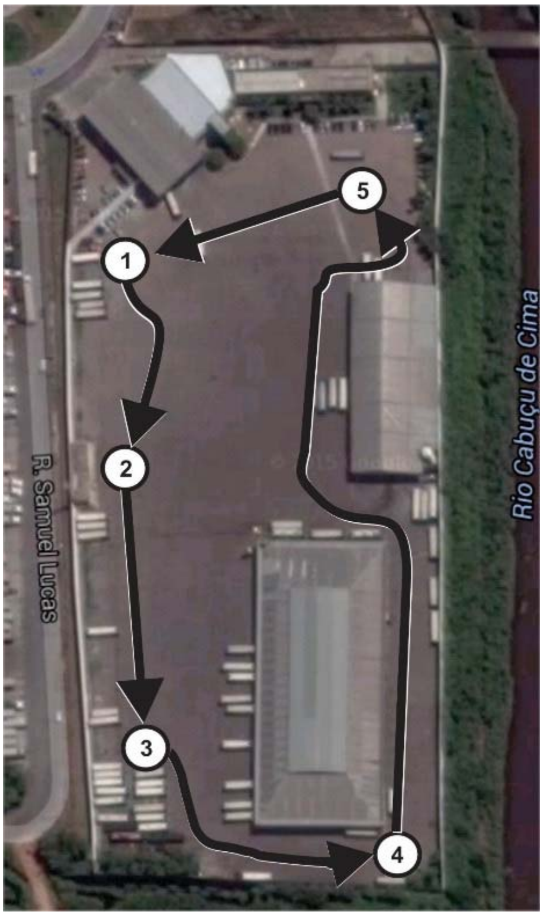

Figure 6 - Stopping Points and the bus route inside the garage to perform the tests - Source: custom of: <https://www.google.com.br/maps/search/-46,608374/@-23.4909017,-46.5616472,491m/data=!3m2!1e3!4b1?hl=pt-BR>

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	time of the end trip	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		second connection		third connection		Total Waiting Time
		Stop bus	Waiting time	Stop bus	Waiting time	Stop bus	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:

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

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					Passengers boardings	FR*
	P1	P2	P3	P4	P5		
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:

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

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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