An operational model of bus terminal management based on daily passengers demands

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Abstract—This article aims to tackle management operational model of public transport as a guideline with the consolidation of the operating efficiency of the municipal bus terminals, based on the use of ubiquitous technology [1] and concept of Big Data [2]. As well to be used in obtaining and processing information of passenger demand, to be collected and processed in real time, in order to maximize resource utilization and fleet operators, to meet the needs of users of the displacement of the system, reducing the waiting time on platforms, shipments and travel providing a better quality of life for the population, as well as the improvement of environmental conditions through the reduction of pollutants into the atmosphere. In this proposed model the main purpose is to qualify transportation services with the enhancement of the use of RFID [3] technology and Big Data [2] for the collection and processing of information by ensuring the implementation of activities based on standards developed by adopting the best practices of work. As well aiming at increase of satisfaction and quality of transportation service.

***Keywords*—**Technology ubiquitous concept of Big Data, needs displacement, quality transportation service, environmental conditions.

I. Introduction

THE city of São Paulo with already industrial city profile, today can be considered as a major pole of attraction for businesses and services, in this way transport systems face each day a greater demand for offsets without the traditional transport planning which can follow this growing trend with proper implementation of urban infrastructure and other necessary investments.

Currently the manager and operator of transport do not have the information in real time about conditions of manning of vehicles and platforms in order to provide available resources at runtime in a rational way, providing better service and flow of movement of vehicles and passengers.

Considering municipal terminals as elements of regional integration, the City's proposed model aims to collect and process data on the daily movement of users in access, shipments, vehicles and the effective use of services (destinations) offered, aiming to reduce the time of passengers waiting on the platform, better use of resources fleet in order to avoid accumulation of vehicles at its facilities and access, providing better fluidity of movement, maximizing performance and avoiding saturation, and this (model) is geared to efficiency, productivity and quality of operation that is extended to the entire mass transit system.

Operational management of the terminal should enforce the use of the information of passengers commuting via public transportation, properly addressed in ITS applications - (Intelligent Transportation System) and Big Data at runtime which in turn rely the advances in telecommunication and positioning via GPS. Taking into consideration the use of other technologies such as Radio Frequency identification (RFID) in the identification of travel profiles through the use of tag in smart card payment (Bilete Unico) cards and readers / antennas installed in vehicles, accesses, platforms and crossing points extending to the terminal corridors and other stopping points of the bus.

The mobility data collected will be used in real time by management, supervision and planning teams in solving performance problems of the system through improving both terminal functioning and services provided by external actors. .

The elaboration and systematization of measures of operating performance was only possible by performing costly field surveys, since data regarding the regional mobility of the population does not include municipal passenger terminals.

The organization of travel distribution will be essential to meet the mobility needs of the city. This management model aims to increase the capacity of transport systems in terminals correlating the various operational elements, creating indexes of fluidity and performance of the operation, based on the conditions of platforms occupancy, access and vehicles considering the best service to be

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provided. The model is also guided by a combination of historical data and the profile of dislocations of users, the occupancy rate of vehicles and points charts that meet the lines involved in axis scroll managed, as well as projections of traffic, in order to increase the commercial speed of buses, safety displacement and reduce the negative impacts of mass transit operations on the environment and mobility in the city.

Such objectives can be achieved by collecting and processing information at runtime, from the integration and interoperability of joint systems and embedded devices as well as in providing a planning framework based on historical data around which can develop permanent interaction between those responsible for monitoring and fleet management, guiding the actions of regulation of the transport system by bus terminals.

Simultaneously, it is proposed to increase the capacity of the remaining operational control centers (Central, Regional and Operator and future Mobility Centre) to track, monitor and integrate preventive actions, especially in sections where saturation of vehicles and road system may occur, or any other type of conditions that may pose risks to the operation of the buses.

Even though the potential for covering various classes of transport, this proposal focuses on management mode of The Passengers Bus Terminal , with the aim of providing improvements in management and care of the user needs and other stakeholders.

A. Context

The city of Sao Paulo has a population of over 10 million inhabitants. If 38 surrounding counties will be added, the result will reach almost 17 million people. In the metropolitan area, about 55% of motorized trips are made by public transport, a total of 6.3 million passengers per working day [4].

To meet the such demand, the city currently maintains 30 municipal bus terminals, 10 of which are equipped with technology (smart terminals) and bus lines operated by private companies, under the management of Sao Paulo Transporte SA - SPTrans. The system is operated by 16 consortia formed by companies and cooperatives, responsible for the operation of 15 thousand vehicles which operate in more than 1300 lines [4].

In accordance with the Law 13.241/01 and Decree No. 43.582/03 is for the city of São Paulo, through the Municipal Transportation - SMT organize, operate and supervise the public transport services in its various modes [4].

The Municipal Transportation System is composed of an integrated network, created by the City Department of Transportation, in conjunction with SPTrans in 2003. Such a network allows quicker shifting and rational use of means of transport in the city. [4]

To better meet the demands of bus transportation in the city mass transit system was divided into two auxiliary and complementary systems:

1) Structural subsystem

Aimed to meet the high demands of displacement that target from various regions and regional centers to the city central areas. To fully meet these connections, this subsystem main characteristic is to operate on the main axes of displacement and transport corridors with vehicles of medium and large size (articulated and bi-articulated).

In the general structure this integrated network service is considered as the backbone of public transport as it provides the connection to the various regions, as well as connects several regional centers to the city center.

2) Local subsystems

Aimed to meet the demands with short displacements needed in outlying areas, especially in places with limited road vehicles and feed the system of structural mesh, allowing the attendance to points of connection with the structural subsystem and/or sub-centers through lines operated by public buses and smaller vehicles, such as: minibuses, small buses and midi-buses.

To facilitate the organization of the lines, the city was subdivided into eight areas, each with a different consortium and cooperative, and the vehicles follow the same color pattern, according to adopted visual identity.

Nevertheless, the implementation of the activity of the public transportation planning at the level of specification is needed. Having in mind that various elements influence the planning process, such as the identification of the basic relationships between the main needs of population, in context of the physical conditions of the neighborhood and other characteristics of the city; the influence of the operating conditions of the transport system and its permeability in the road system.

In order to regulate, guide and monitor the implementation of the provided services OSO's-Service Orders by the Managing Operating System are issued which stipulate the amount of matches, fleet type and other characteristics for the performance of the activity by the dealer or grantee of public transportation system.

B. Problem

With a lack of knowledge of the relationships between displacements and the other conditions of the city as well as its influences on the services of public transport, regulation through the execution of orders (OSO) is insufficient to understand due to the unfavorable conditions to the transaction, whether in a particular terminal or in its background and feeder systems (structural and local).

Regarding the complementary operational measures, which must be taken into account to restore normal operation, the indicators of production and productivity should be considered (capacity and demand; occupation of platforms and intermediate points; contracted level of service and commercial medium speed).

Exceptionally service orders do not show adaptability in adverse situations (meteorological factors, heavy traffic, strikes and other events) that may alter the conditions of service causing discomfort to users.

There are currently no means of telling with the online Monitoring System SPTrans if any service is being impaired, in this case those responsible for the supervision and control of the fleet, communicate to teams of monitoring and management, to the operator to replace certain vehicle (broken or damaged in a traffic accident) or forwarding a particular service to a particular point of the line or terminal, in order to avoid losses on the needs of displacements of the system users.

Do not always the decisions taken by the management team of operation produce an effective monitoring, as determined correction action of a specific problem in a line, may trigger sequence of adverse events that may cause deregulation of the system, including: increased waiting time at bus stop, increase in travel time, increase of saturation levels of service in bus terminals and the worsening of unfavorable conditions of the flow due to the insertion of a service on a road already saturated.

Besides these situations, the operations of terminals in the central areas of cities are influenced by scarcity of physical space for operation and internal circulation, as well as the traffic conditions and access. Such factors may cause delays in the scheduled departures due to greater accumulation of passengers on platforms and increasing the waiting time and boarding the vehicles.

During morning peaks central terminals have large flow of vehicles approaching the bus lines more frequently operating, with platforms space not sufficient to accommodate all the buses arriving in the terminal and passenger demand relatively lower compared to the peripheral terminals in the same time.

In this case, the vehicles tend to wait for the departure time while the others move between platforms waiting for space parking. In this situation, operators have capacity of peripheral terminals reduced to the maintenance of the scheduled fleet , generating the accumulation of users on the platform, and in some cases the vehicles are only released for departure after the arrival of another vehicle of the same line, causing the cascading effect.

Depending on the geographic location of the terminal in the city and the design of the public transport network, the fluctuation of supply in various parts of the system results in greater movement in the terminal, often surpassing its ability to meet the pent-up demand in platforms. The traffic generated as a result of these facts affect the circulation of buses and vehicles in their vicinity in general.

Another fact to be added to understand the behavior patterns of users in a given terminal, in some cases it is observed that during the morning boarding peak passengers use the first vehicle available, while in the afternoon peak there is trend to wait in line for less crowded bus to travel sitting.

C. Purpose

This article aims to apply the methodology and use of ITS (Intelligent Transportation System) tools , integrating the information acquired in the module for monitoring and controlling the fleet together with the adoption of new models of operational management.

Furthermore, it allows the adoption of knowledge for the operational management from Terminal Transfer, allowing these urban facilities greater autonomy in control of the services, with the use of monitoring information across spatial location latitude and longitude of embedded devices (GPS / AVL [5]),the data collected and processed in real time, using the technologies of data collection, radio frequency - RFID , using tag (to be installed in public terminal equipments, breakpoints and corridors and Smart's charge cards - Bilhete Único) combined with historical data of the displacements of users via public transportation [7] .

The information provided to assist management teams in system operation and decision making adjustments to the regulation of services, determined by the orders of operation service(OSO), taking into account the level of current service in vehicles and approximate ratio of users on the platforms of the terminal.

The proposed model will maintain correlations with the conditions of fluidity of regional transit and other related factors that can change the characteristic of the operation or the commercial speed, with the premise of providing information to users about the conditions of manning of vehicles approaching and alternative displacement, based on the application of the concept of systems with big data.

The proposed these technologies in conjunction with the new management model may provide a better understanding of the behavior of the transport system, allowing the validation of proposed models with the current conditions (reprogramming, changes lines), filling partially empty gap within the existing literature with regard to the basic principles of planning and operation with the reality of the system.

D. Relevance

The relevance of this topic is given to the fact that the system monitor the real-time location of buses, following the evolution of its service level according to the behavior profile of demands over the route of the line. The quality of transport is also related to the capacity of the vehicles, and the users' perception, the last parameter depends on the period in which passengers use the system.

In this case, the evaluation of the capacity factor is through the relationship between the number of passengers inside the bus and its stretch and critical period, to maximum capacity and vehicle capacity.

With the identification of tag of payment cards and other embedded devices (AVL / GPS [5]) any change of pattern in the level of service in operation, saturation of demand in terminals or intermediate points of the bus lines will be communicated to the teams of System Management and monitoring.

The management model can provide alternative service based on:

1) Current conditions of displacement of passangers compared with historical data source and destination [7] and the evolution of the displacements at runtime of tags;
2) Application of projection level of service using parameters employed by the management of services, which will be calculated based on a combination of established quality standard data of manning of vehicles in operation lines (Ferraz , 1990), monitored at runtime collected from tags (Mauricio Lima 2013) emarged with historical data for demand response in the intermediate and terminal points;
3) Recommendation of measures to regulate the operation of services allocated in accordance with the minimum standards for occupancy of the terminal platforms, based on the provisions of the Transit Capacity and Quality of Service Manual 2nd Edition (Part 7/Station and Terminal Capacity) including fleet availability and operational costs;
4) Provision of information for the planning teams and managers of service provider, to improve the adequacy of the terms of schedules of work orders (OSO) according to changes in demand or other factors arising;
5) Indication of teams that have irregular operating conditions or level of service at runtime in order to be monitored, as well as finding irregularities, and further penalisation;
6) Service of contingency systems until a situation of discrepancy can be bypassed (eg strikes, high capacity, adverse weather conditions, demonstrations, blocked traffic, and other system failures).

II. DEVELOPMENT

Terminals allow passengers to make bus travel between points of interest so they can freely choose between various combinations in order to reach destination. Performance measurements can be made on the operational conditions of the whole system, since that is where greater intensity the problems of operation of lines and corridors are reflected with.

The proposed model of management operation terminal provides with information displacements of users at run time, based on of data collected by the antennas RFID readers installed at the access and circulation areas of people and vehicles.

This process of automatic exchange of data between the device middleware [6] RFID system, filters, and aggregate identification labels tag that RFID reader processed with spatial reference latitude and longitude of embedded devices (GPS / AVL [5]).

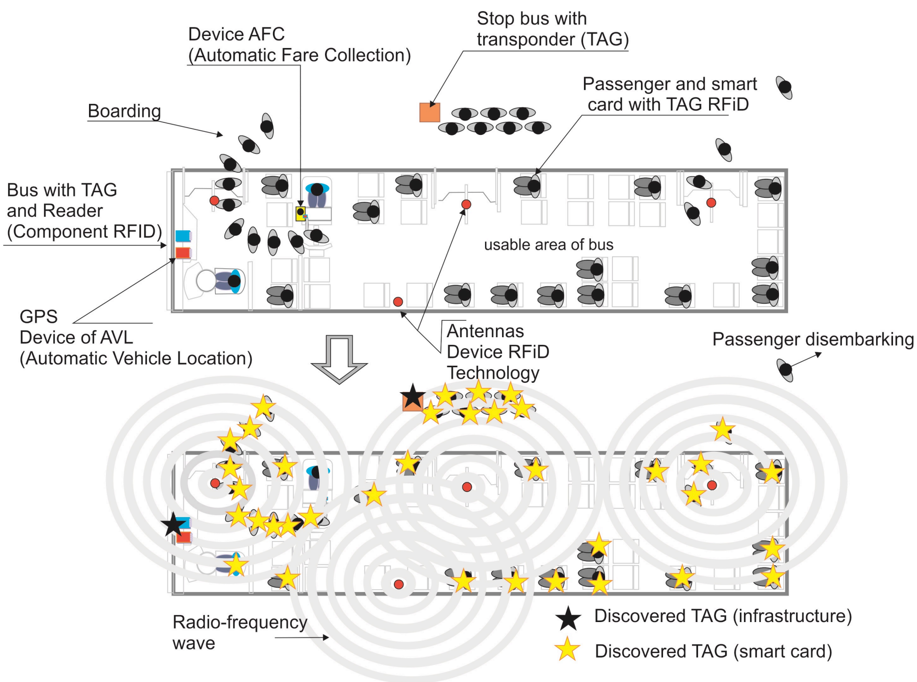

Fig. 1 - Proposed model for data collection by tags – Maurício Lima 2013
Source: M. Lima, E. Dias, 2014, Real time monitoring of public transit passenger flows through Radio Frequency Identification - RFID technology embedded in fare smart cards, (in print

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For determining the level of service contracted, combination of the following procedures should be applied:

1) The proposed data collection by tags - Maurício Lima (2013);
2) Historical values of the exchange supply and demand;
3) Conditions for saturation of platforms and standards levels of service as the manning of vehicles Ferraz (1990) [8], which in Table 01, the lower the density of passengers, the better the quality of the transport service.

Table 01 - Standard quality manning of vehicles [8]

Level of Service	Density (Passenger/m2)
A	Only sitting
B	0 a 1,5
C	1,5 a 3,0
D	3,0 a 4,5
E	4,5 a 6,0
F	>6,0

Source: Ferraz (1990)

4) For the conditions of saturation of the terminal platforms on the proposed study the adaptation of service-level model is needed for common circulation area (TCQSM, 2003) [9] with:

- Level of Service "A" - Walking speeds freely selected; conflicts with other pedestrians unlikely.

Fig. 2 - Level of Service ‘A’
Source: TCQSM, 2003

- Level of Service "B" - Walking speeds freely selected; pedestrians respond to presence of others.

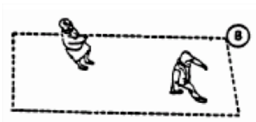

Fig. 3: Level of Service ‘B’
Source: TCQSM, 2003

- Level of Service "C" - speed walk freely selected; unidirectional flows there can be shocks; minor conflicts in the opposite direction and crusaders motion.

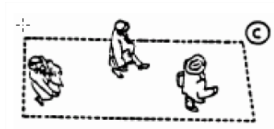

Figure 4: Level of Service ‘C’
Source: TCQSM, 2003

- Level of Service “D” – Freedom to select walking speed and pass others is restricted; high probability of conflicts for reverse or cross movements.

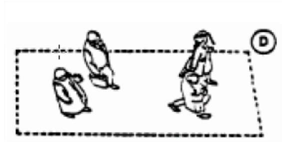

Figure 5: Level of Service ‘D’
Source: TCQSM, 2003

- Level of Service “E” – Walking speeds and passing ability are restricted for all pedestrians, only forward movement is possible; reverse or cross movements are possible only with extreme difficulty; volumes approach limit of walking capacity.

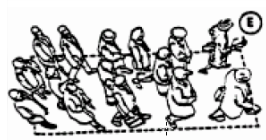

Fig. 6: Level of Service ‘E’
Source: TCQSM, 2003

- Level of Service “F” – unavoidable contact with others; reverse or cross movements are virtually impossible; flow is sporadic and unstable.

Figure 7: Level of Service ‘F’
Source: TCQSM, 2003

With the use of all information collected allied to parameters defined by the management of services, the

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breakeven point for the management of the terminal will be established, taking into account the economic and financial aspects applied to each operation of the bus lines involved.

In addition to the information relevant to the operation of the terminal, with each pass of the vehicles equipped with the system of collection in a particular notable point (bus stop, transfer or terminal control line-TP/TS station), new data submitted by equipment embedded (GPS / AVL [5]) being sent to update the system.

This update will be performed based on the concepts of Big Data technology, the processing of data collected from vehicle to vehicle from point to point of its operation, with the other information coming from other related systems (fleet management and tracking of buses, traffic and information system planning with origin and destination of travel [7]), statistical data for composition that will form the basis for generation of alerts inconsistency of the transport system at runtime.

All alerts are associated with operation indicators and other parameters of calculations that focus on saturation of the bus service, as well as monitoring the general profiles of dislocation (demand) through the alignment of data users at the point of capture or transfer stations where serve as input to guide the actions of regulating the public transport service by the management teams of transportation and transit.

Consignments of such information and alerts to the monitoring system will be handled through the respective control centers by management teams operating. The purpose of this procedure is to enhance supervision of services and fleet management and monitoring of the situation of the road, rows of terminals and corridors that offer greater risks degradation of service by the public officials and operators of the system.

The information system will maintain historical conditions and the movement of vehicles on the data lines, as well as monitoring through management reports and indicators in order to guide the planning actions aimed at continuous improvement of the service specification and the development of specialized routines for performance of inspection teams in the field of transport system.

This proposal aims to assist the management of the main system in the monitoring of potential risks based on:

1) Treatment alerts cartographic databases (points charts with zoom levels and saturation);
2) Temporal transmission parameterized by the monitoring system data concerning the probable movement of the demands aiding decision making processes in the implementation of fleet resources rationally and effectively, considering the performance indicators, resource availability and costs;
3) Identification of control data events, with possible "bottlenecks" in the operation of commercial speed or fall because of road impedances and propose based on the demand profile and historical data and load flow solutions;
4) Serve as the basis of knowledge in the application of contingency operations in situations of deadlock of other modes of public transport or other adverse;
5) Preparation of management reports for analysis planning teams and costs for improving the applied models;
6) Providing information on system conditions in real time to the general public.

III. IMPROVEMENTS

Besides knowing the location of public transport vehicles the user can check the conditions of occupation of vehicles approaching in order to get more comfortable ride.

Using data collected from embedded devices, system managers can evaluate the performance of the operation, plann interventions through estimates of arrival rates of the lines and the conditions of arrival of demands in a particular stop point or terminal.

Recognizing the critical points of the bus lines and suggest service solutions, considering the array of destinations [7], elaborating scenarios of changes in demand profiles for each modification or correction of work orders (OSO).

Provide support to managers and urban planners to develop guidelines for transportation plans through management of indicators of services.

Monitor system performance in the context of actions taken to further analysis of the results.

Make public the information of system performance to all stakeholders by issuing periodic reports.

Suggest new bus lines/connections rationally based on displacement [7] array to improve the quality of care, with better use of staff resources and vehicles.

IV. CONCLUSION

The management model for measurement of performance function support the planning and management of specific and adverse problems, logistical support for decision-making processes, promote continuous improvement of the system as well as improved operational control using as reference historical database.

The proposed study aimed to present the analysis of data with relevant information on the density, flow and displacement of passenger terminals in the public mass transit system, that will:

1) Reduce the cost caused by waste or mis-sizing of the terminal features;
2) Make the provision of services closer to the need to travel for passengers;
3) Allow pro-active rescheduling of services based on the systematic evaluation of recurrent changes in the use of supply;
4) Develop new tools for informing users about the conditions and ocupation of vehicles and other public

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transport facilities;

5) Application of technology in places of embarkingn and disembarking in order to contribute to the operational services regulation avoiding the saturation of the terminal;
6) Produce database with inputs for the composition of inspection plans of the bus lines, which include higher accuracy and improved use of inspection teams;
7) Promote the allocation of resources and services according to the need to travellers in critical situations;
8) Systematicall collect and analyse the data on the conditions of the platforms, points of stops and passenger capacity in the vehicles of the public transport system;
9) Reduce the points of congestion caused due to long embarking and disembarking due to excess of demand and intermediate stops;
10) Provide greater flexibility in the allocation of resources based on the assessment of demands, avaliable resources and space allocation;
11) Undertake immediate correction of data aimed at increasing the commercial speed and comfort of the user.

The ubiquitous technology can adapted both in the concept and design, to use other personal communication devices such as mobile phones, tablets and other devices or with Bluetooth technology to collect data essential for management teams operation for organization and monitoring of the system, providing however, that the user can provide information in real-time about the conditions of the transportation system.

Drafting new management model similar to those applied in activities of port terminals, using identification of approaching vehicles and their levels and quality of service with the purpose to optimize the use of physical space and streamline operations through the provision of bus bays or in response to different traffic flows and demand.

Within the contrasts with the conventional schemes, where all lines have pre-designated bays, the new systems function under normal circumstances. However when one bus is late, triggering high density of passengers on the platform, the dynamic system can automatically relocates other vehicle to a nearby free bay, accommodating passengers waiting of the platform.

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[2] http://oglobo.globo.com/infograficos/bigdata/ *(Accessed: May 2014)* Big Data is the set of technological solutions capable of handling digital data volume, variety and velocity unpublished until today. In practice, the technology allows us to analyze any type of digital information in real time and is central to decision making, it is able to handle unstructured data included in these geolocation and behaviors that depend on a context to have meaning.

[3] *http://www.gta.ufrj.br/grad/071/rfid/RFIDarquivos/Index.htm (Accessed: May 2014)* RFID technology (radio frequency identification - Radio Frequency Identification) is nothing more than a generic term for technologies that use radio frequency for data capture. So there are several methods of identification, but the most common is to store a serial number that identifies a person or object, or other information, on a microchip. This technology allows automatic data capture, to identify objects with electronic devices, known as electronic tags, tags, RF tags or transponders that emit radio frequency signals to readers that capture this information. She has been there since the 40s and came to complement the technology of bar code, widespread in the world.

[4] *http://www.sptrans.com.br/pdf/biblioteca tecnica/* (Restricted access, accessed: May 2014)

[5] *http://www.mundogeo.com (accessed: Jan 2014)* The Acronym AVL (Automatic Vehicle Location which means, ie, automatic vehicle location), defines systems where GPS technology is used for monitoring vehicles. Since GPS is designed to provide primarily expresses the vehicle's position in geographic coordinates. The system consists of a network of satellites in various orbits arranged so that any point on the planet.

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