Group 9 BRUNO TADEU MADERA

EDPO COVALCIUK SILVA

FABRICIO MATOS SOUTO

JOÃO CARLOS GONÇALVEZ CONDE FILHO

LEANDRO JOSÉ ARAÚJO SILVA

VIVIAN DE SOUZA TAZIMA

Ticket System with QR Code Technology

São Paulo

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Final project presented to CNT / Deutsche Bahn for the title of International Management in Railways

São Paulo

2019

Ticket System with QR Code Technology

Abstract: *The usage of ticketing systems is of fundamental importance for the railway sector and it's continuously management is part of companies´ routines in this sector, which becomes more competitive every day. Special attention is given to the inefficiency of costs on O&M. Allied to this problem, new technologies lead to different effects in the known system, which demands continuous research and practical validation of the results with possible opportunities of gains in the productive process without, obviously, reducing the availability and offer to the passengers that use it in its displacement daily. This project presents the satisfactory results of the integrated tests between a new QR Code technology for ticketing systems and solutions. Finally, it is concluded that such methodology has a satisfactory operational result and financial feasibility in place.*

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Keywords: *QR Code, Ticketing, railway, operational efficiency.*

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LIST OF ABBREVIATIONS

CPTM	Companhia Paulista de Trens Metrô-SPpolitanos
Metrô-SP SP	Companhia do Metropolitano de São Paulo
QR Code	Código Quick Response
MTBF	Mean time between failure
MTTR	Mean time to repair
O&M	Operation and Maintenance
ATM	Automatic teller machine
OPEX	Operational Costs
CAPEX	Capital Expenses
IRR	Internal rate of return
WACC	Weighted average cost of capital

SUMMARY

1. CONTENT

1.1. INTRODUCTION

To access paid sections of stations from both CPTM and METRÔ-SP SP, ticketing systems are applied as controllers to proper manage income. This control is often applied with blockades (electronics or mechanicals).

A monthly average of 25.810.445 passengers enters the stations using Smart Cards, representing 73,92% of total passengers (excluding gratuities by law). On the other hand, more than 9.108.446 uses Edmonson type tickets representing 26,08%.

Edmonson type tickets were widely used on previous decades becoming a classical form of accessing railway systems in Brazil. Nowadays, its commercial use is strictly used for one-way tickets contrasting with SmartCards that are commercialized on several different layouts and applications.

To use different technologies, at the same time, imply on data limitations at controlling them and also increase bot costs for operating and maintaining them. Therefore, this project intends to present different available technologies (with pros and cons) and its impacts on passenger’s daily routine, focused on improving their experience.

1.1.1. CONTENT

To control the access of passengers to the paid areas of the stations and enable the validation of the travel right, CPTM / Metrô-SP SP uses its own ticketing system, which consists in the selling of Edmonson-type magnetic tickets at ticket offices set up at stations, in addition to the municipal agreements, which use contactless cards.

In the past decades Edmonson Tickets have been widely used on railroads around the world as a classic form of ticketing. Today, however, the technology they use is obsolete in terms of safety and reliability, as well as the high costs inherent in their operation (transportation, maintenance, storage, etc.) when compared to other models.

The technological advances of recent years have brought with it the need to adapt to the new passenger profile, which demands greater daily agility. In this sense, a great availability of technologies presents itself as an alternative and opportunity for the evolution of the means of validation of the right of travel, which in addition to becoming more agile will enable new ways of commercialization and use of the tickets through electronic devices and internet.

It seeks to acquire a new way of marketing and validation of the travel right that should facilitate and simplify the use, being friendly and naturally incorporated into the daily routine of the passenger in accessing the stations. This new technology must meet the current needs of its passengers and: (i) promote the management and control of tariff collection with lower operating costs; (ii) reduce the number of system failures, and (iii) and reliability of transactions.

With the insertion of a new technology, the ticketing system should expand the forms of marketing of travel rights, not only of the Metropolitan service, but also of other modalities that CPTM / Metrô-SP SP may implement through: (i) automated terminals (ATMs) and points of sale (POS / Tablet), (ii) digital platforms, (iii) application for mobile devices and (iv) commercial partnerships. It should also reliably store the information obtained with the billing, allowing the visualization of sales data and use in real time, with centralized control and production of customizable reports.

1.1.2. GOALS

The goal of this work is to verify the applicability of the ticket system using the QR Code technology in CPTM and Metrô-SP SP stations, considering costs, risks and technical feasibility.

1.1.3. JUSTIFICATIVE

The ticketing system currently in place at CPTM and Metrô-SP SP works by acquiring and processing data from all families of tickets and cards.

This implies the management and operation of different technologies, each with a specific degree of complexity, impacting on different operational and maintenance routines, which end up entailing different costs for the company.

That said, this document proposes technological alternatives for the replacement of the Edmonson platform magnetic tickets as a means of validating travel rights in CPTM's/Metrô-SPs SP ticketing system, in order to improve information management, fight obsolescence, reduce operating and maintenance costs, and provide a better service to passengers through all the data gathered on a more modern system.

1.2. BRIEF DESCRIPTION OF THE CHOSEN TOPIC

Currently, at the CPTM / Metrô-SP SP stations, validation of the travel right occurs only at the moment of the passenger's embarkation, and no type of validation is used at the time of leaving the paid areas of the stations.

The current model of ticketing system deployed is able to operate by accepting two different technologies as forms of validation of the travel right (Edmonson Platform or Smart Card). This fact implies in the use of different equipment for the operation of these two technologies, besides entailing the use of specific architectures for the acquisition and transmission of the data.

These two types of technology used in the ticketing system, in addition to providing different levels of security, data reliability, management and control of the collection information, have a direct impact on the way passages' access the stations, as well as the personnel routine operational and maintenance conditions at stations

In the current molds, the ticketing system employee is shown with a complex structure of operation, not allowing the adoption of standardized single solutions for any change or interference, and it is necessary to adapt the actions so that the two ticketing models are always operational.

While the passenger can enjoy the advantages of modern ticketing technologies, obsolete magnetic ticket technology is still maintained in order to serve those passengers who do not have any Smart Card in their possession, that uses the CPTM / Metrô-SP in an eventual form or even one that does not have the resources to register and acquire a smart card.

The quantitative data on the use of the Edmonson Tickets are not obtained electronically and there is no automated reporting that provides additional data that can assist the management / control of the information regarding the ticketing.

The lack of reliability in obtaining data on the use of this type of ticket indicates that the management of ticketing system information is further hampered by the use of equipment with a high number of occurrences of failures.

The equipment used in the turnstile to read and collect the Edmonson Tickets, have recurring failures due to the fact that they use in their constitution many mechanical components, subject to detrition and malfunction.

Often there is the so-called cram, where the Edmonson Ticket gets stuck in some of the components that are used to make its movement after insertion to the internal storage compartment in the turnstile. Whenever this occurs, there is a need for the displacement of operational and maintenance personnel to carry out the intervention at the site of the failure.

Delays in boarding passengers, interferences in the normal flow of passengers' movement at the station and temporary decrease in the capacity to meet demand may occur due to such interventions.

The technology employed in the manufacture of this type of ticket has historically been susceptible to fraud, lacking security devices that reach a level close to the levels desired with the deployment of more current technologies.

The use of different technology platforms in the ticketing system negatively impacts the routine of operational and maintenance personnel, as well as entailing an increase in costs for CPTM/Metrô-SP SP.

The costs related to each type of ticket / card used are directly proportional to the failure rates caused by the use of these in the CPTM/Metrô-SP SP turnstile. Taking into account this information, it is verified that the use of Edmonson Tickets causes most of the occurrences of failures in the CPTM/Metrô-SP SP turnstile.

The high intrinsic cost of using the Edmonson Ticket contrasts with its low usage, with its average monthly cost being about five times higher than the costs associated with using Smart Cards, but its use is approximately three times lower.

The constant displacement of personnel to solve problems of operation in the turnstiles and recurrent failures in the ticket itself means that there is a high man/hour value spent exclusively to attend to these occurrences.

In addition to the failures caused by the use of tickets / cards, the turnstiles are still subject to common failure inherent in their operation. Failures are classified systemically and operationally. The systemic failures are those that are intrinsic to the ticketing system. Operational failures are the sum of systemic failures with those of external origin and that impact the system (vandalism, flood, etc.).

The implementation of the payment method using the QR Code or the Smart Card in the ticketing system, besides solving the problems related to the high intrinsic costs of the whole process of confection, transport, operation and maintenance of the Edmonson

Ticket, also allows features and additional functionalities of these technologies can be exploited, representing more advantages for CPTM / Metrô-SP SP.

Although the ticketing system has as its fundamental objective the collection of tariffs and the access control of passengers to the transportation system, the selected ticketing technologies are provided with scalability, allowing their shared use with other applications.

Among the possible additional functionalities, we can cite:

- Creation of new alternatives to passengers to acquire the right to travel;
- Generation of new sources of revenue;
- Multiple applications.

These are just some of the features that these types of payment provide, since they are technologies with good information storage capacity and flexibility of use, allowing you to open perspectives beyond those strictly programmed initially (Edmonson Ticket replacement). The main characteristics of the QR Code (Quick Response Code) technology are:

- Higher data density than other images, with storage capacity and security level compatible with performance parameters;
- Various levels of information retrieval in case of partial loss of the image, since the code allows the creation of redundancies;
- Non-positional reading, that is, the code can be read in any arrangement, with 360º variation in the positioning in the validator;
- This type of code uses a pattern that is widely diffused in the world in several applications, which can facilitate the realization of commercial partnerships;
- Low deployment and operational costs when compared to more sophisticated code and higher levels of security and storage.

1.3. RESEARCH RESULTS

In the year 2015 CPTM transported an average of 69,287,445 passengers per month, with a monthly average of 34,918,891 paying passengers, representing 50.4% of the total. In order to control the access of passengers to the paid areas of CPTM stations and to manage the collection, a ticketing system is used.

In the ticketing system, the control is performed through electronic or mechanical blockades. These blockades allow access to the paid areas of the stations to occur with the purchase of the travel right through the purchase of tickets or electronic credits.

A monthly average of 25,810,445 passengers access CPTM stations through smart cards, representing 73.92% of total paying passengers. Meanwhile, a monthly average of 9,108,446 passengers enters the stations with the Edmonson Ticket, which represents 26.08% of the paying passengers. Among non-paying passengers, 78.34% use smart cards, a monthly average of 3,397,317 passengers.

At CPTM, Edmonson tickets were widely used in previous decades, consolidating as the classic form of ticketing used on the railroad, with its use fully incorporated into the routine of the passenger and the operational staff. Currently the Edmonson Ticket is only sold in unit mode (a travel right), while Smart Cards are made and marketed in several modalities, with varied layouts and parameterized functions, assigning a card mode for each different type of passenger and tariffs.

Smart Cards represent the natural evolution of technology in ticketing systems around the world, while the magnetic tickets of the Edmonson platform show themselves to be holders of a technology currently considered obsolete, both for safety and reliability reasons, and because of costs (transport, maintenance, storage, etc.).

In 2013, Smart Cards were present in the transport systems of 77% of the Brazilian cities with a population of more than 50 thousand inhabitants, and it is present in 100% of the transportation systems of high demand. The technologies most used in high-capacity transportation billing systems currently in Brazil are presented below:

Table 1 - Technologies often used on ticketing systems

Technology used in ticketing	Sharing technologies (%)
Only Smart Card	89
Smart Card and paper ticket	4
Smart Card and Paper tickets	7

The adoption of different technologies in the ticketing system, each with its own characteristic, implies in limitations in the control and acquisition of the data, besides raising the costs for the operation and maintenance of the system.

In this way, this study seeks the best possible way to operate a billing system, through the application of more modern technologies, allowing the adoption of standardized measures and unique and well defined procedures, including problem solving, always opting for those which reduce operating costs, streamline and simplify the maintenance process, and ease passenger routine. At CPTM stations, the validation of the travel right occurs only at the time of the passenger's shipment, and no type of validation is used at the time of leaving the paid areas of the stations.

The current ticketing system model implemented at CPTM is able to operate by accepting two different technologies as forms of travel validation (Edmonson Platform or Smart Card). This fact implies in the use of different equipment for the operation of these two technologies, besides entailing the use of specific architectures for the acquisition and transmission of the data.

These two types of technology used in the billing system, in addition to providing different levels of security, data reliability, management and control of the collection information, have a direct impact on the way passengers access CPTM stations, as well as the routine of operational personnel and of maintenance in the stations. Below is a schematic of the routine of the passenger access to the paid area of the stations at the moment of entering and leaving the paid section at CPTM:

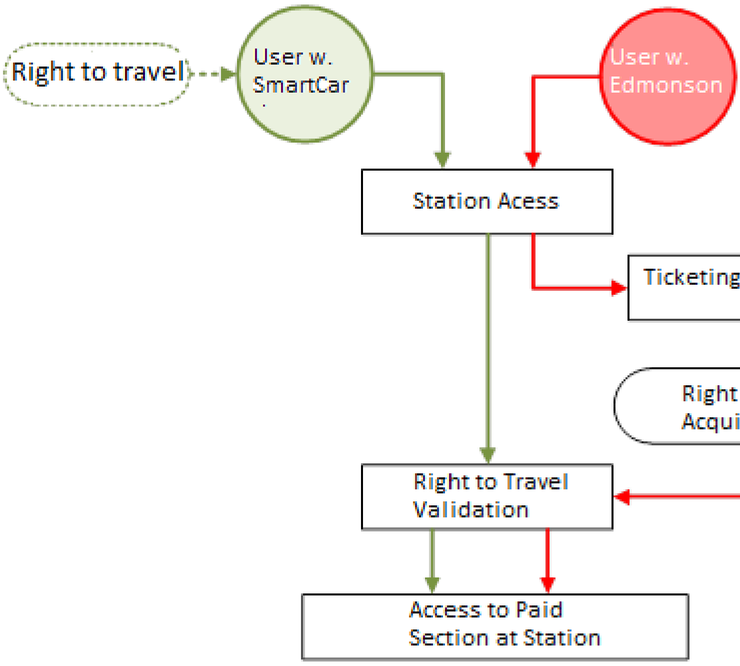


Figure 1 - Passenger workflow accessing the paid-section of a typical station

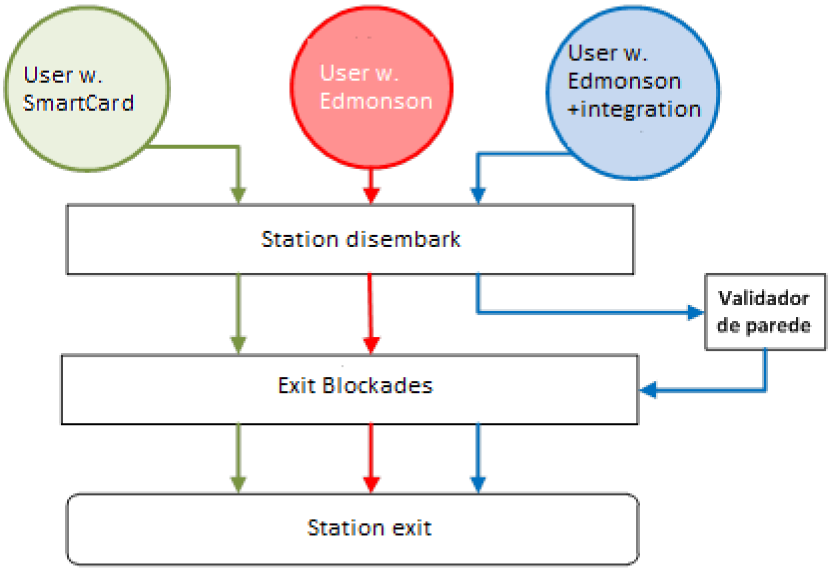


Figure 2 - Passenger workflow leaving the paid-section of a typical station

1.4. HYPOTESIS

The ticket system used in CPTM is shown with a complex structure of operation, not allowing the adoption of standardized single solutions for any change or interference, and it is necessary to adapt the actions so that the two models of ticketing are always operational.

At the same time as the passenger can take advantage of modern ticketing technologies, obsolete magnetic ticket technology is still maintained to serve those passengers who do not have any Smart Card.

The following are the main components of the ticketing system employed by CPTM:

- Equipment validation of travel rights (blockades installed);
- Means of payment (cards and tickets accepted);
- Communication architecture (data acquisition / transmission system).

1.4.1. EQUIPMENT USED AT CPTM

Many types of blockades are used from different manufacturers and use different technologies to perform the access control in the stations. When taken into consideration the way of functioning, these blockades can be divided into two categories, electronic blockades and mechanical blockades.

When considering the type of ticket / card that the blockades can carry out the validation of the travel right, the blockades can be of two types, those that are able to read magnetic cards (Edmonson Platform) and those who read smart cards.

The following is the number of blockades currently in the CPTM lines.

Table 2 - Block quantities installed at CPTM

Blockades installed at CPTM			
Lines	Electronic	Mechanical	**Total per Line**
Line 7 - Rubi	90	9	**99**
Line 8 - Diamante	87	80	**167**
Line 9 - Esmeralda	97	51	**148**
Line 10 - Turquesa	89	57	**146**
Line 11 - Coral	76	26	**102**
Line 12 - Safira	186	15	**201**
CPTM	**625**	**238**	**863**

I. BLOCKADES WITH MAGNETIC TICKET READER

On blockades with magnetic ticket readers, the passenger must insert the Edmonson ticket into the appropriate slot in the blockades, the ticket is then retained and it can access the station. For passengers that use integrations with municipal bus service its necessary use of a specific Edmonson ticket, so, the equipment does not retain this ticket, returning it to the passenger and it can be inserted in the wall validators located in the paid areas of the stations.

Figure 3 - Blockade with magnetic reader

This equipment has a stand-alone reader, which locally processes all magnetic tickets and has a high maintenance cost due to the use of gears and other mechanical components, being subject to natural wear and tear of parts. The magnetic ticket used in this type of equipment has low manufacturing cost and high failure rate.

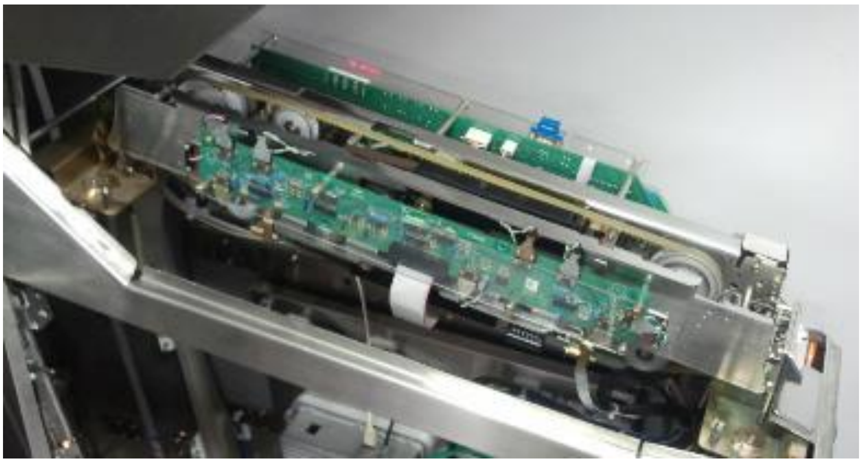


Figure 4 - Internal mechanism prone to high failure

II. BLOCKADES WITH SMART CARD READER (VALIDATOR)

On blockades with smart card readers, o the passenger approach your card from the validator and shortly after the access is released and it can enter the paid areas of the station.

Figure 5 - Smart Ticket blockades

In this type of equipment an online communication with the server network is performed. It also has off-line processing capability, with storage capacity greater than fifteen days. Compared to magnetic card reader equipment, the cost of maintenance is lower because it has no gears and other mechanical components and is less subject to component malfunction and natural wear of parts.

III. BLOCKADES WITH EDMONSON READER AND SMART CARD VALIDATOR

In these blockades, the passenger has an option to pay your trip through Edmonson ticket and smart card accepts in CPTM. This equipment has the function of not segregating the passenger by the way in which they will carry out their validation of the trip right, and there is no need to direct then to specific blockades according to the ticket / card that they have. This method there is less interruption in the flow of passengers in the line of blockades.

Figure 6 - Edmonson and Smart Ticket Blockade

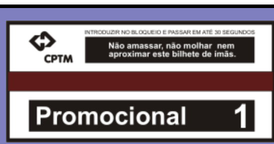
1.4.2. TICKETS TYPES ACCEPT IN CPTM

I. MAGNETIC TICKET – EDMONSON

This is a ticket made mostly by a cardboard compound (rectangular longline) with standardized dimensions (30 x 66 x 0.25 mm), with a magnetic stripe, where they are engraved and read the travel entitlement information.

The reading and writing of data occurs through the physical contact of equipment (reader / writer) with the magnetic stripe. In this way, the use of this type of ticket implies the use of blockades with magnetic card reader, which raises the maintenance cost due to the use of mechanical components subject to wear and tear.

Table 3 - Edmonson type available today at CPTM

			
F-01	***F-36***	***F-41***	***F-23***
For One-Way tickets.	Bus integration at Barueri, Itapevi and Jandira stations	Bus integration at Mauá Station .	Weekend only usage with 50% discount (Only for enterprises use).

II. SMART CARDS

Smart Cards are those that do not need to be inserted into reader by the passengers to perform validation. The reading and writing of the data are performed by approaching the card in the validators (VBS), making these procedures to be performed faster, compared to those performed through the magnetic ticket reader. Since it is a contactless card, the Smart Card dramatically reduces the costs of maintaining equipment. The lock used to read this type of card does not require magnetic card reader, reducing the amount of mechanical components and, consequently, reducing the cost of maintenance.

Smart cards have functions that allow the physical and tariff integration between passenger transport services on CPTM rails and bus services. All Smart Cards accepted in CPTM use the same technology platform, MI fare Standard from Philips.

1.4.3. NETWORK ARCHITECTURE FOR TICKETING PROCESSES

Regarding the acquisition of the ticketing data, the CPTM station blockade lines are arranged in two different configurations: autonomous blockades, which operate independently and are not connected to any centralization element and blockades with local data centering, which have an architecture that allows monitoring and control of the data locally. Currently in CPTM, of the 90 stations in operation, 65 have blockades with local data center, representing 72.22% of the total stations, while 25 stations have autonomous blockades, representing 27.78% of the CPTM stations.

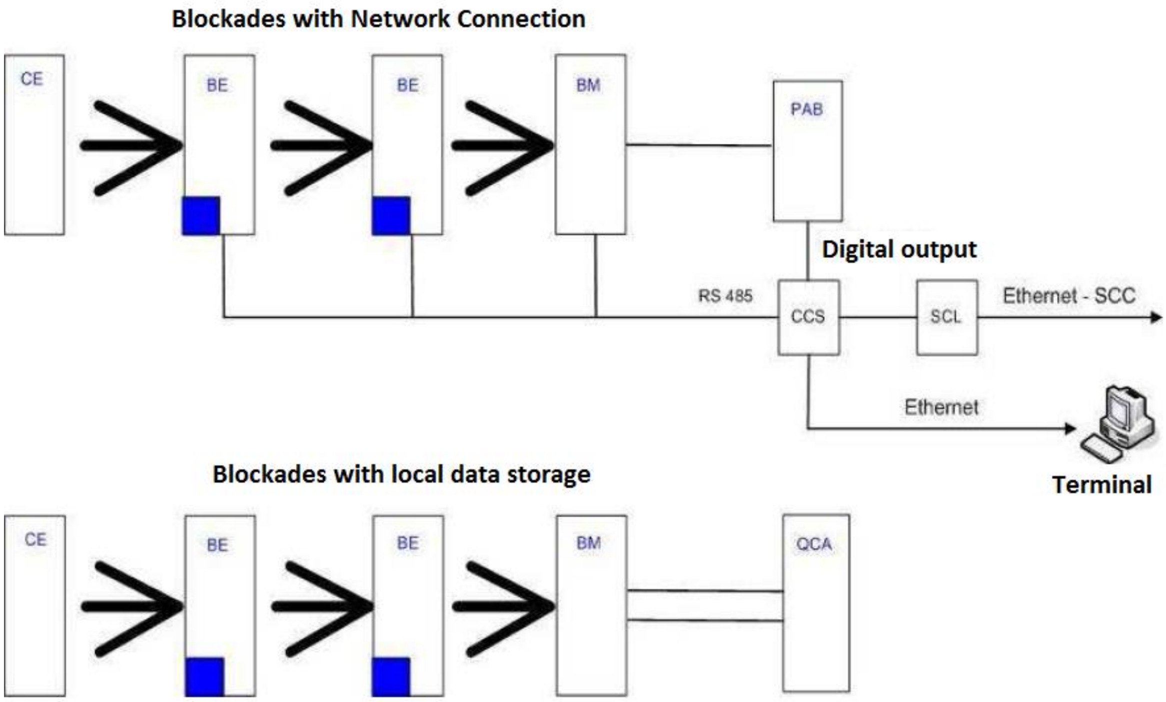


Figure 7 - Blockades architecture with local data storage

Each of the smart card systems currently deployed at CPTM has a different configuration for data acquisition and transmission.

I. SMART CARDS ARQUITECTURAL SYSTEM

Smart Cards use architecture for the acquisition and transmission of billing data. The deployed system distributes the data first to the server in the CPTM, and then the transmission is made to the integrating servers, allowing integration between the CPTM system and the bus service systems.

This architecture provides reliable operational data and allows the issuance of financial reports to support the meeting of accounts among the tariff integration integrators.

The following is a schematic diagram of the architecture used in the acquisition/transmission of smart card usage data in the CPTM billing system:

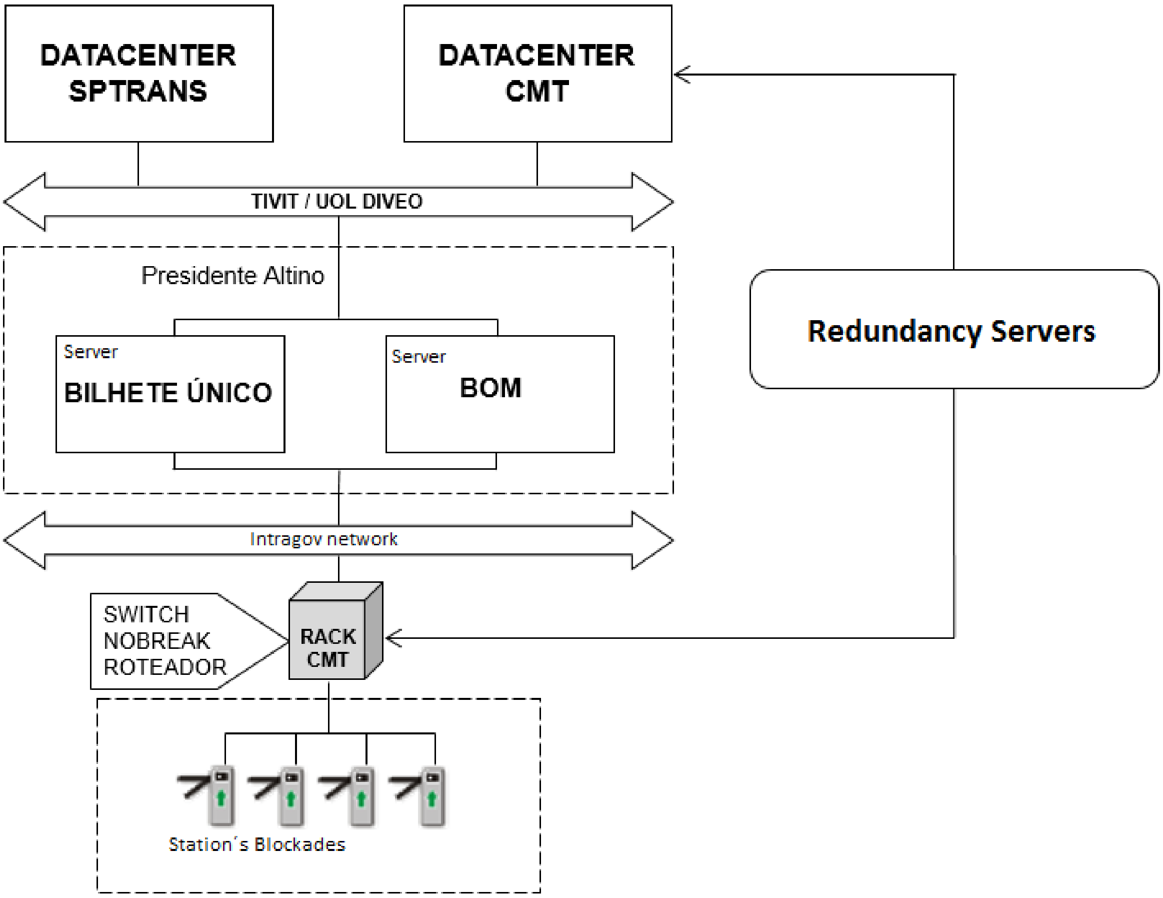


Figure 8 - Receiving and Transmitting data between CPTM, Bilhete Unico and Cartão BOM systems.

II. SMART CARD AND EDMONSON INTEGRATION ARQUITECTURE

In this system, the installed architecture causes the data acquisition to be processed by the Intranet of CPTM network and then distributed to the collections. In this way, it allows the operation of the integration between the CPTM system and the bus service system that aggregates Edmonson ticket credits.

As it is a system that uses, in addition to a Smart Card, the Edmonson F-36 Ticket, it is needed to install additional equipment, the Green Validator module, at CPTM stations where physical and tariff integration takes place with the municipal bus system.

This equipment allows the transfer of credits from the Edmonson F-36 magnetic ticket to Benfácil Card, allowing the use of travel rights in the municipal buses of Itapevi, Barueri and Jandira.

This architecture also provides operational data and enables the issuance of financial reports to support the meeting of accounts among the tariff integration integrators. The following is a schematic diagram of the architecture used in the acquisition / transmission of Smart Card and Edmonson ticket usage data:

1.4.4. EDMONSON TICKET PERFORMANCE

The use of different technological platforms in CPTM's billing system negatively impacts the routine of operational and maintenance personnel, as well as entailing an increase in costs for CPTM.

The cost related to each type of ticket / card used are directly proportional to the failure rates caused by the use of these in the CPTM blockades.

Taking into account this information, it is verified that the use of Edmonson Tickets causes most of the occurrences of failures in the CPTM blockades. The high intrinsic cost of using the Edmonson Ticket contrasts with its low usage, with its average monthly cost being about five times higher than the costs associated with using Smart Cards, but its use is approximately three times lower.

The constant displacement of personnel to solve problems of operation in the blockades and recurrent failures in the ticket itself means that there is a high man-hour value spent exclusively to attend to these occurrences.

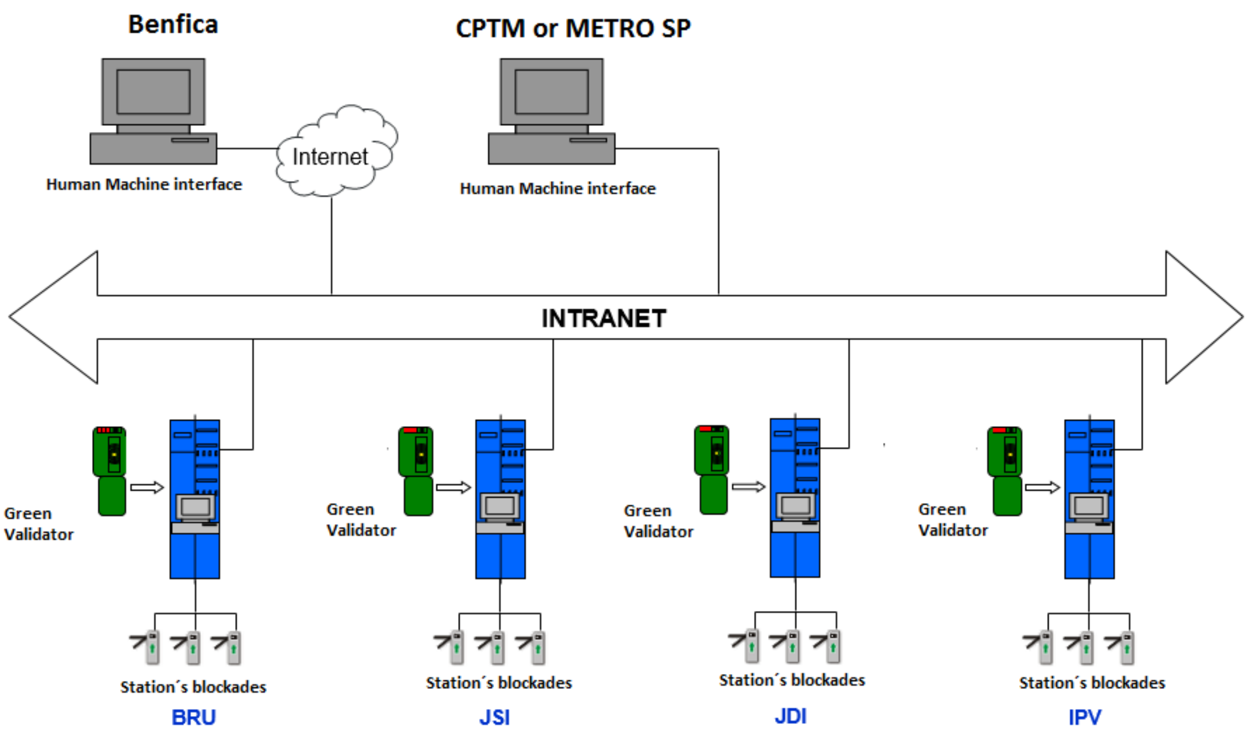


Figure 9 - Receiving and Transmitting data between CPTM and Benfácil systems.

In addition to the failures caused by the use of tickets / cards, the blockades are still subject to common flaws inherent in their operation. Faults are classified systemically and operationally. The systemic failures are those that are intrinsic to the billing system. Operational failures are the sum of systemic failures with those of external origin and that impact the system (vandalism, flood, etc.).

For the measurement of performance and availability index of the blockades in the CPTM, two indices are taken into account, the **MTBF** (average time between failures) and **MTTR** (mean time of repair). In the calculation of these indices two types of failures are considered, systemic and operational. In this study, the operational indexes will be used, since they are the ones that effectively measure the total unavailability of the blockades.

The following table shows the failure and MTBF values of the CPTM blockades in total numbers and the monthly average per line for the year 2015.

Table 4 - Blockade´s MTBF and MTTR for 2015

CPTM Lines	Annual Total		Monthly average		
	Failure	MTBF (hour)	Failure	MTBF (hour)	MTTR (hour)
Line 7 - Rubi	1351	6480	113	538	4:12:16
Line 8 - Diamante	1382	12275	115	1020	16:08:32
Line 9 - Esmeralda	1790	8458	149	699	16:19:46
Line 10 - Turquesa	1465	9524	122	777	21:12:29
Line 11 - Coral	3103	3283	259	271	3:42:20
Line 12 - Safira	2407	4593	201	371	11:22:12
CPTM	**11.498**	**6565**	**958**	**545**	**11:03:32**

Considering total number of failures occurred in the CPTM blockades, 53.7% are common failures resulting from normal usage of the blockades, regardless of the type of ticket / card that was used in the validation of the travel right. Examples of such failures are tripod problems, vandalism, power shortages, etc.

Meanwhile, 46.3% of total blockade failures are related to the use of certain type of ticket. Of these failures, we can verify that the great majority (76.6%) is related to the use of Edmonson Ticket. This information can best be seen in the following graph:

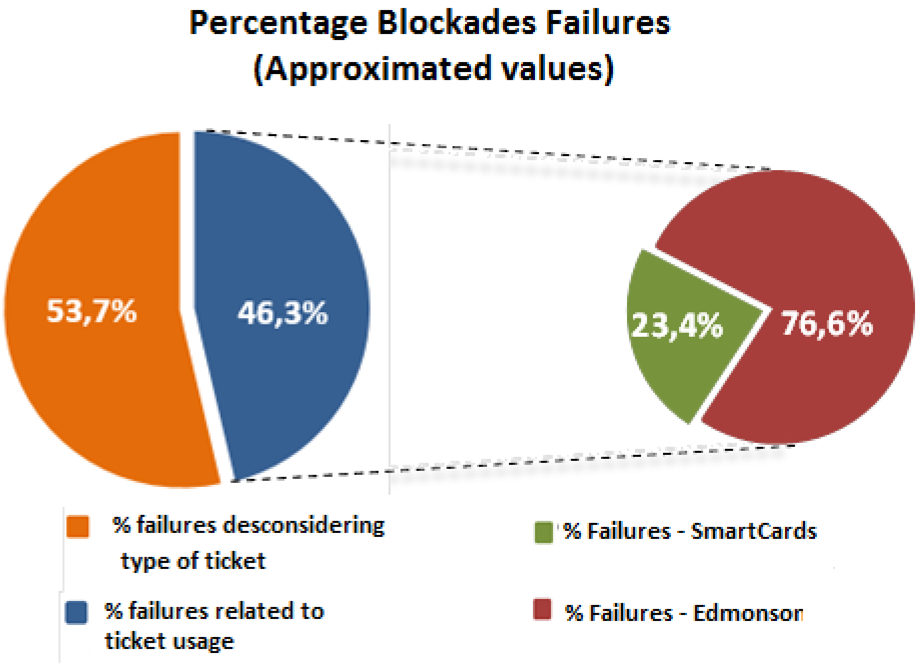


Figure 10 - Percentage distribution for failures related to blockades - 2015

After data analysis, it is showed that 96.9% of the failures occur in the electronic blockades, and this type of equipment totals 68.8% of the total blockades installed in the CPTM.

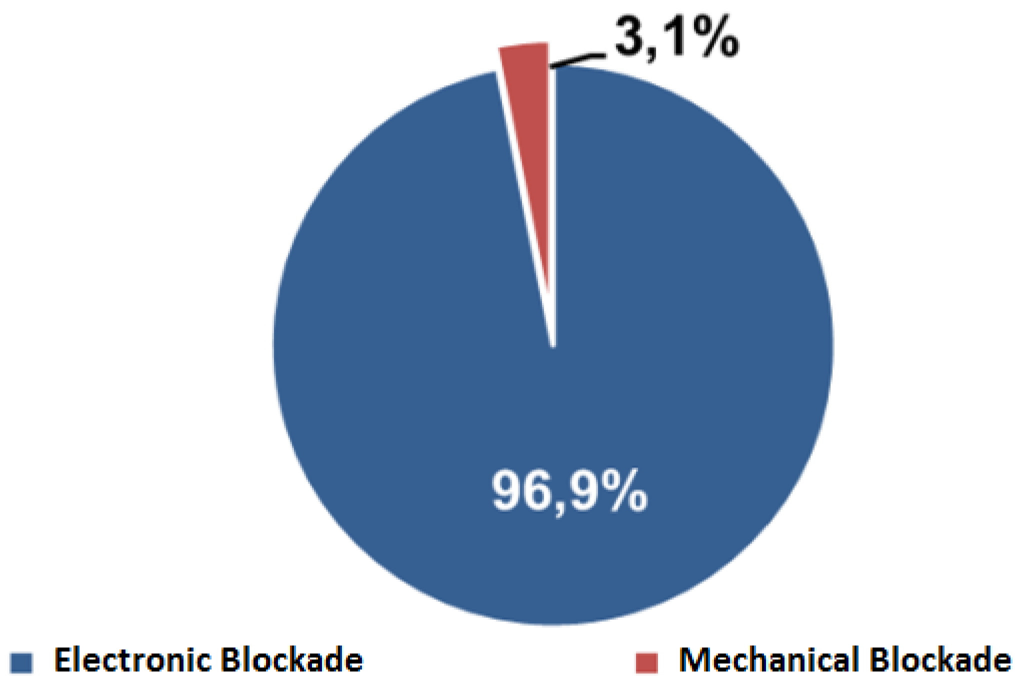


Figure 11 - Distribution of failures between electronic and mechanical blockades

Considering all lines operated by CPTM, Line 11 - Coral is the one that presents the highest percentage participation in the total failures occurred in the CPTM blockades in 2015, representing 25% of occurrences. The chart below shows the share of each row in the total number of failures that occurred in the CPTM blockades in 2015.

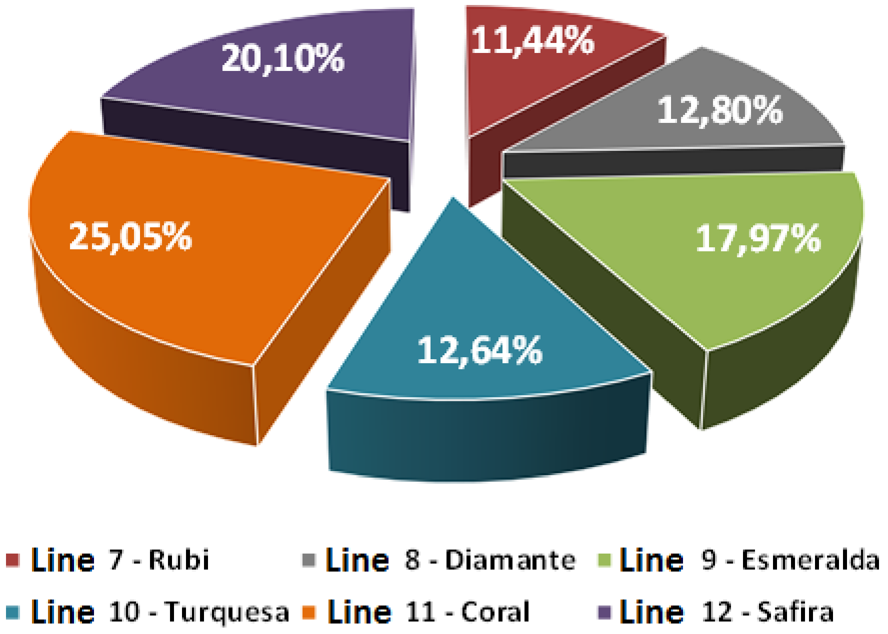


Figure 12 - Failures distribution considering all lines operated by CPTM

In order to measure more adequately the influence of the failures occurred in the blockades, the availability index of these equipments is used, which is a percentage numerical value that expresses the time that the equipment remained available for use.

The availability index of the blockades in the CPTM stations is calculated using the following equation:

$$\frac{MTBF}{MTBF+MTTR} \times 100\%$$

Figure 13 - Availability calculation

The blockades, per CPTM line, presented the following monthly average percentages of availability in 2015:

Table 5 - Availability results for 2015

CPTM Lines	Availability average (% for 2015)
Line 7 - Rubi	99,22%
Line 8 - Diamante	98,44%
Line 9 - Esmeralda	97,72%
Line 10 - Turquesa	97,34%
Line 11 - Coral	98,65%
Line 12 - Safira	97,03%
CPTM	**98,01%**

The bad figures due to high number of failures related to the use of the Edmonson Ticket in the blockades, impairs the passengers access to the stations and, consequently, implies the adoption of operational strategies to mitigate these effects.

Considering that (i.) a blockade is used to enter the station access has a capacity of attendance of 17 persons per minute, for each hour that a blockadeage remains unavailable, the attendance capacity of the station, with respect to the inflow of passengers, is decreased by 1,020 passengers; and (ii) that they are dimensioned to meet the demand of each station, the intermittence of problems in these equipments directly affects the quality of the service provided by CPTM, damaging, even more, the company's image as a service provider.

1.5. GENERATE IDEAS

Magnetic technology (Edmonson Ticket) has been used on a large scale in railway systems and has proved to be appropriate over the years for unit and multiple tickets, albeit of shorter durability and potential for fraud.

Together with technological evolution for billing systems and mainly the means of payment to acquire the right of travel, a great availability of tickets or cards came to be presented as alternatives to the technology of the Edmonson platform.

All types of smart cards meet the needs of automated tariff collection systems, which may differentiate the adoption of one technology over another, showing that the important feature in this decision process is the set of desired functionalities associated with the costs of deployment and operation and maintenance.

Not all technologies for controlling passenger input / output through pre-purchased credit validation have the ability to integrate with data acquisition / transmission, and are suitable for an automatic billing system but not as useful in electronic ticketing system.

The following will describe the technologies that can be used as a means of payment of the right of travel in the ticketing systems for the transport sector with its advantages and disadvantages.

1.5.1. Bar or QR Codes (Quick Response Code)

They make use of a technology that is widely used in various commercial establishments and as access control, including temporality, but little used in the transportation ticketing sector.

A code is printed and information is stored in it, for example, the time and place of the purchase of the travel right. This information can be confronted with the codes generated in a system, so that validation can be performed.

The use of this type of technology generates the need to update the data in real time, therefore, the communication between the reader and the ticketing system must be online, in order to avoid fraud, avoiding that a printed code and already used is passed on to another passenger after the validation of the travel right.

Figure 14 - Bar Code and QR Code printed on low cost paper.

For use in ticketing systems in transport, the use of QR Code can be considered, since it has an information storage capacity greater than the Bar Code, besides offering a higher level of security, without promoting because it is a more sophisticated and advanced encryption.

I. ADVANTAGES

- The ticket office can print quickly and on very low cost paper, a bar code or a QR Code, which can be validated in low cost readers;

- They can be perfectly adapted to a ticketing system, since with online communication, generated and validated codes in the readers can be easily controlled;

- Financial reports may be issued and other information generated to help better management of billing information (e.g. hours of use, direction of travel, etc.);

- The reading can be done in 360 °;

- The QR Codes reader uses a technology that is cheap and widely used in a wide range of sectors, with free readers available for use on any Smartphone;

- Ticket highly resistant to dirt or distortion.

II. DISADVANTAGES:

- Full-time online communication implies the existence of a very robust data connection with high availability, so that there are no data transmission failures and that the generated codes can be properly disabled in an instant next to the real time of use in order to avoid possible fraud;

- The need for the use of trash cans or other places for deposits by passengers of tickets already used.

1.5.2. Inductive and Resistive cards

This technology was widely used in telephone cards, which were manufactured to be used in public fixed telephones.

This type of carton, through a PVC-enclosed structure, has small cells composed of a thin metallic layer, carrying micro switches (fillets), which are burned with each use. Each of these micros fuses represents one bit of information.

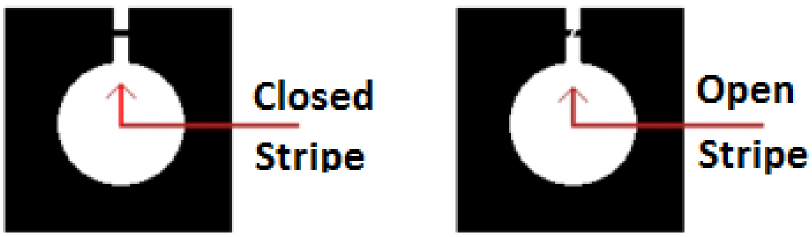


Figure 15 - Inductive Card internal cell representation

In this way it can be concluded that each intact cell corresponds to a travel right. These will be burned at each use by introducing into an appropriate validator. As the fusion of the cells is irreversible, the card becomes unusable when all intact cells are exhausted.

Figure 16 - Telephone card and ticketing system for transportation using the same technology.

I. ADVANTAGES

- Technology quite robust the attempts of frauds. The safety of the inductive card lies in the difficulty of having the technology necessary for its manufacture;
- Relatively low cost compared to other card technologies.

II. DISADVANTAGES

- This type of card does not store or transact alphanumeric information;
- Its application is limited to simple operations of unit cards and multiple trips, and its reuse is not possible. They do not involve complex schemes of temporal integration, since it would be necessary to record on the card the hour and minutes of the last shipment, which would be possible, but would consume many cells;
- In addition, they need to be inserted in readers and removed after the reading and burning of the credit cells, which causes an increase in the time spent by the passengers for the shipment;
- They do not fit perfectly into an electronic ticketing system, since data cannot be transmitted to a control / supervision system;
- In this way, there is a good control over the sale of travel rights, but it is not possible to add any additional information of this passenger to the system, only the amount of sales / use.

1.5.3. Magnetic ticket/cards

These types of tickets / cards are capable of storing and transmitting alphanumeric information, having an average storage capacity, ranging from 128 bits (most usual) to 512 bits.

This storage limitation may negatively impact the use of this type of ticket / card technology in an electronic ticketing system, depending on the amount of information regarding the intended use.

They support temporal and spatial integrations, limited to their storage capacity. They can be manufactured in low and high coactivity, to avoid magnetic interference.

They can also be reusable, though they have much lower durability than smart cards.

Included in this technology are chip less credit cards (in ISO 7816 standard format) and Edmonson Tickets.

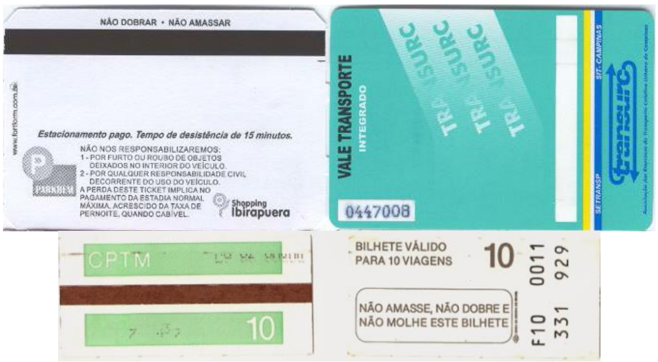


Figure 17 - Magnetic cards used for both parking and transportation services.

I. ADVANTAGES

- Low acquisition cost compared to other card technologies;
- Way of use already consolidated in the routine of passengers;
- It may be reusable, although such capacity is not used in the CPTM system.

II. DISADVANTAGES

- It is a technology that is very susceptible to fraud. The information stored on these cards can be cloned with low cost equipment or gadgets;
- They have low durability compared to other card technologies;
- Have a very high index of data read / write failures;
- This type of ticket / ticket needs to be inserted in readers that employ many mechanical components, with a mechanism of transport of the same so that it passes, at a controlled speed, by the read / write heads. This mechanism contains moving parts and fine mechanics, being very susceptible to wear and tear, which greatly increases the operation / maintenance costs;
- They do not integrate perfectly to an electronic ticketing system, because after the validation of the travel right in the readers, it is not possible to add any additional information of this passenger to the system, only the amount of sales / use;
- Low useful life in the case of paper ticket making. For confection in other structures, there is a slight increase in the shelf life;

- It can lead to an increase in the time of shipment of passengers, due to the need of insertion in equipment for the reading / writing of data.

1.5.4. Contact memory (Button)

This technology has some advantages in uses with access control systems, but its use in the transport sector is still very low, although the few experiences in the industry are attractive for fraud inhibition, durability and reliability.

The Button consists of a chip encapsulated in a stainless steel case, shaped like a coin or metallic button, storing inside it micro-processable memories. It has on its internal chip a unique and inviolable serial code, impossible to be copied. It is extremely robust, weatherproof, shockproof and water resistant.

They differ from smart cards only by the physical medium that carries the memory, as it also has a storage capacity very similar to those types of cards.

Data read / write is performed through the contact between the metal surfaces of the Buttons and the readers with at least 15% of the connected areas without requiring specific positions.

This technology has the storage capacity of up to 2MBytes (16Mbits). It has a fast data read time, and its operating temperature range is wide, ranging from -40 ° C to + 85 ° C.

It has the greatest protection against environmental aggressiveness, allowing Button-based access control systems to be installed almost anywhere, even in environments where temperature variations are quite high.

Figure 18 - Button Contact Memory

I. ADVANTAGES

- Very high security level;
- Very long service life (over 10 years, the highest of all technologies presented);
- High reliability in data transmission (immunity to interference);
- Fast reading time of the data;
- High storage capacity of information;
- Reusable for many times.

II. DISADVANTAGES

- Higher manufacturing cost (the highest of the technologies presented here);
- The need to use an apparatus for fitting / depositing in the equipment that will read / transmit the data;
- Increase in the complexity of the actions to be taken by the passenger;
- High cost of issuing a duplicate;
- Despite the speed in reading the data, the passenger's boarding time can be increased if we consider that it is necessary to insert the Button into an appropriate slot;
- Its reduced size can facilitate that it is lost;
- Type of technology that needs to be incorporated into the routine of passengers.

1.5.5. Smart Cards

This type of card is subdivided into two basic families: memory cards (Smart Card Conventional) and micro processed cards (Micro processed Smart Card).

In the case of micro processed cards, the integrated circuit includes, in addition to memories, modules (microprocessors) that provide it with processing capacity. Memory access security is highly enhanced by the use of established, non-proprietary cryptographic algorithms.

The technology of microprocessor cards is not the most used in the transportation sector due to its higher cost, caused by a processing capacity and use of a level of security much greater than those required by a billing system.

Memory cards are those that are typically used in electronic ticketing. It uses standard Philips MI fare Standard technology (predominant in Brazil).

The Smart Card has a more affordable cost and processing capacity more suitable for use in transportation billing systems.

The table below shows the worldwide production of Smart Card by application area (in millions of units):

Table 6 - Smart card production in 2013 by niche (presented in million)

Area	Conventional Smart Card	Microprocessor Smart Card	Total	%
Telecom	1.000	400	1.400	76,8
Financial	0	200	200	10
Fidelity	40	15	55	3
Safety	0	18	18	1
Television	0	40	40	2
Government/Health	25	40	40	2
Transportation	55	15	70	3,5
Other	25	12	37	1,7
TOTAL	**1.146**	**780**	**1.926**	**100**

The table above shows that the use of Smart Cards in the transport sector is mostly made up of smart cards, representing approximately 79% of the total use of Smart Cards in this sector. For this reason, the present study will address the characteristics of the conventional Smart Card, by its application of the transport sector.

As far as information storage is concerned, Smart Card attributes can be compared to magnetic cards, but with increased storage capacity up to 1KByte (8Kbits) for the contact card and up to 4KByte (32Kbits) for the contactless card . Smart cards carry a microchip that usually has a substantial level of processing and a memory. Hence, more adaptable for complexity.

Here is the basic structure of the interface (contacts) of a Smart Card's chip:

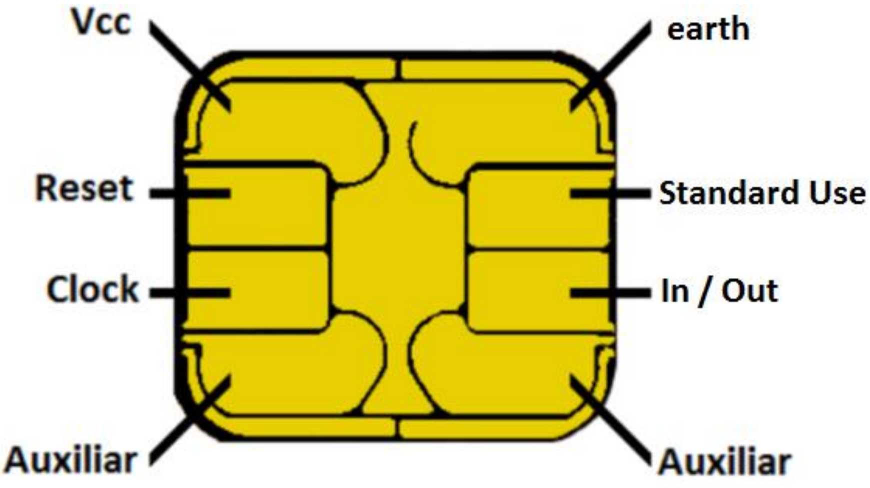


Figure 19 - Chips´ structure

I. ADVANTAGES

- This type of technology presents the best levels of security observable in the cards used as means of payment in the billing systems;
- Allows the improvement of the planning and control of the transportation offer. With numerous information available, managers and operators have tools to compare the planned operation with the one carried out, to subsidize the analysis of the discrepancies and guide in the formulation of improvements;
- All data acquisition is done in an automated and electronic way, facilitating the control and management of all billing information;
- Tariffs can be established considering: periods of the day (peak of demand and off peak), days of the week, direction of travel (by validation in the exits of stations), categories of passengers (discounts for students, senior citizens, etc.), integrations between modal and passenger loyalty with daily, weekly, monthly or annual packages. Because all of these categorizations are configurable, the system manager can easily enter / change this data;
- Control over the issuance of electronic credits and the balance of travel credits on the cards, including the authentication of the electronic credits of the system;
- Possibility of implementation of multiple applications;
- Long lifespan of approximately 10,000 uses;
- Reduction of operating and maintenance costs.

II. DISADVANTAGES:

- Higher manufacturing cost;
- The use of this type of card implies the need of a system that is quite robust and with high availability;

- If there is a need to issue a 2nd route, the cost is much higher;

- The need to use clearing houses for the control and management of the collection of tariffs, being able to be own or of third parties.

1.5.5.1. Smart Cards Types

Conventional Smart Cards (memory cards) can also be classified by the way the memory contacts and read / write the data with the readers, being subdivided into categories, contact smart cards, contactless smart cards and hybrid smart cards (contact and non-contact).

- **Contact**: data exchange is given by direct contact of the exposed chip with the reader / writer.

- **Contactless**: information is exchanged by electromagnetic waves, with several wires passing through the card, serving as an antenna for communication and power.

- **Hybrid**: works in two ways, with shared memory and processor.

1.5.5.1.1. Contact smart cards

It needs to be inserted into a reader. The card receives the energy from the validator and from there it can carry out the transaction. This contact cannot be interrupted during this operation.

Usually it has a rectangular format standardized, elaborated in variations of plastic cardboard, plastic, polymer or other variants.

Figure 20- Contact Smart Card type

This technology is widely used in bank cards (debit and credit). There are applications where this type of technology is employed in association with magnetic ticket technology (chip and magnetic stripe).

In these cases, the main advantage of the magnetic ticket, its low cost, begins to decrease, because it becomes necessary to increase its durability with the use of plastic, PVC, or other materials, besides increasing it coercively, so that it is not subject to magnetic interference.

In this case, it is also necessary to take your storage capacity to the maximum limits and use encryption, to reduce the possibilities of fraud always present.

The type of technology used in Smart Card with contact implies an increase in the time spent by the passenger to access the station's paid area, due to the insertion procedure of the card in the reader and the respective data read / write time.

In addition, the likelihood of data read / writes failures are increased due to the need for the physical connection between the equipment and the card not to be susceptible to interference.

Figure 21 - Contact Card type structure

I. ADVANTAGES

- Relatively low cost of manufacturing compared to contactless carton, besides the possibility of cost reduction with mass production;
- Made available by several suppliers;
- Technology already consolidated in the routine of passengers, due to its application in several other areas;
- High durability;
- Standardized by ISO and CEN;
- Possibility of using automatic points of sale and recharge and / or via the Internet;
- Possibility of generating other sources of revenue.

II. DISADVANTAGES:

- This card requires the insertion in validator or reader, which implies in the adoption of equipment that can raise maintenance costs, if compared to the contactless card;
- Read / write data can be interrupted by bad contacts between the surface of the chip and the reader equipment;
- Increase in shipping time compared to non-contact cards;

- Restricted use to the transport sector and banking networks;
- Electromechanical failures due to wear on card contacts caused by handling, excessive dust in the environment, or even overuse.

1.5.5.1.2. Contactless smart cards

This is the technology of Smart Cards already consolidated in the state of São Paulo, and the medium most used in CPTM and Metrô-SP SP for allowing easy integration with the bus service.

This card only needs to be approached by the reader, without the need of touching it. The reading / transmission or recording of the data is performed through radio waves and antennas existing in the cards as well as in the readers, therefore, there is no physical contact between the two of them.

It has an adjustable proximity field, i.e. the passenger can normally keep a distance from his / her card between 2 (two) and 10 (ten) centimeters of the validator / reader

Figure 22 - Contactless Smart Card type

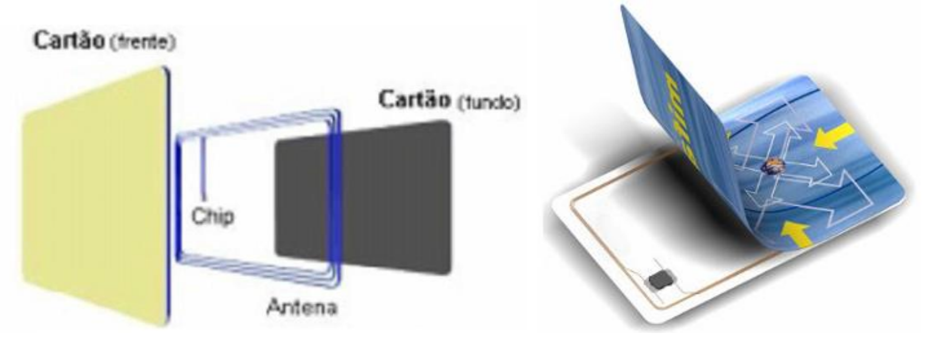


Figure 23 - Contactless Card type structure

I. ADVANTAGES

- Simplified use;
- Very small validation time;
- High durability;

- Reduced maintenance costs in equipment, as it does not require readers with gears or other mechanical components;
- Technology already consolidated in the routine of the passengers, by the wide use in transport systems;
- Possibility of using automatic points of sale and recharge and / or via the Internet;
- Possibility of generating other sources of revenue.

II. DISADVANTAGES:

- Multiple use still restricted;
- Intermediate confection cost, due to lack of mass production;
- Cost of acquisition of equipment (validators) higher;
- Need for the use of clearing house.

1.5.5.1.3. Hybrid Card

The card works through both interfaces (contact and contactless), and may have two interconnected chips, one for each interface, or a single chip, powered by both.

These cards can be validated by contactless and contactless equipment, allowing the interface of the public transport systems that use the Smart Card without contact with the automated banking services.

In this way, there is the possibility of an electronic coin application, being accessed by both interfaces, so in one interface an amount can be loaded in the bank, for example, and in another, a value can be discharged as payment of the travel right .

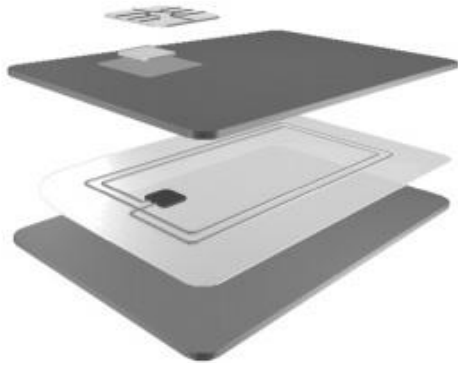


Figure 24 - Hybrid Smartcard structure

I. ADVANTAGES

- Includes the functionalities and advantages related to the Smart Card without contact, plus the possibility of adding the automated banking services.

II. DISADVANTAGES:

- All disadvantages are the same as those related to the non-contact Smart Card, plus the increase in the cost of making the card.

1.5.6. Defining the most suitable technology

The survey of the needs that the system of billing presents should be considered as fundamental in the decision process of the change or not of the technology employed.

The needs of the transport operator and its passengers must be taken into account so that the measures adopted facilitate and promote better management and control of tariff collection, reduction of operating costs and maintenance.

In addition, the chosen technology should facilitate and simplify its use, showing itself as something friendly that can be naturally incorporated into the daily routine of the passenger in accessing the stations.

After analyzing all the implications of adopting the current billing system model (Comparing with Edmonson), the needs to be considered in the decision process were defined:

- Improve revenue evasion control;
- Ticketing safer and more robust fraud attempts;
- Possibility of flexible tariff (by direction, by schedule, by modality, etc.);
- Improve the quality of the information obtained with the billing, using these as a tool in improving the management of the system;
- Reduction of operating and maintenance costs;
- Modernization of management, operation and maintenance processes;
- Possibility of other sources of resource generation: Exploration of advertising space;
- Use of a technology that allows the incorporation of technological advances over time and that are useful for improving the management / use of the billing system (use of technology not sealed);
- To guarantee a more efficient service to the passengers and with a fast access of these to the paid areas of the stations;
- Ensure that the passenger that attends any CPTM/Metrô-SP SP station equipped with a full fare can acquire their travel rights and enter the station's paid area normally;
- Multiple applications: Possibility of aggregation of other services / functionalities to the card used in the CPTM and Metrô-SP SP;

- Enable the purchase of tickets in an easy way, not restricting only the ticket office of CPTM and Metrô-SP SP. (i.e. ATMs, internet, partnerships with other sectors, etc.);

- Enable the return of the investment made in the shortest possible time;

- Improve the company image.

Each of the available ticket / card technologies that have been previously presented have features that make them applicable in a ticketing system, presenting advantages and disadvantages in different criteria in order:

- 1º Low Implementation / Operation / maintenance costs.

- 2º Low impact in passenger routines

- 3º High control and management of tariff collection and the possibility of generating other sources of revenue.

The following table shows an overview of parameters to any technologies studied.

Table 7- Comparison between technologies

Characteristics	QR Code	Inductive Card	Magnetic Card		Smart Card			Button
			Paper	Polymer	Contact	Contactless	Hybrid	
Average Life Spam	Small	3 years	Small	9 years	3 years	10 years	3 years	10 years
Reuse (times)	0	0	0	500	10000	10000	10000	10000
Safety	Very high	High	Average	Average	High	Very high	High	Very high
Costs per ticket (US$)	Very low	90,00/ thnd	20,00/ thnd	50,00/ thnd	1,00/ each	1,50/ each	5,00/ each	5,00/ each
Hardware costs (US$)	Low	2000	3000	2500	1500	1500	1500	2000
Maintenance Costs	Low	Low	High	High	Low	Low	Low	Very low

Source: ABB PRODATA-2005

Comparing the characteristics presented above we can discard the technologies Button, Smart card with contact and hybrid, magnetic card and inductive card, using the criteria (weights) previously adopted.

Finally, relating the characteristics shown above, we can observe that the two technologies of means of payment that were not excluded in any of the evaluated criteria were the Smart Card without contact and the QR Code. The figure below shows a summary of the comparative analysis of each type of billing technology.

Table 8 – Technologies´ matrix for comparison

Characteristics	Desirable	QR Code	Inductive Card	Magnetic Card		Smart Card			Button
				Paper	Polymer	Contact	Contactless	Hybrid	
Start-up costs	Very Low	Very Low	Average	Very Low	Low	Average	High	Very High	Very High
O&M costs	Very Low	Very Low	Average	Very High	Very High	Low	Very Low	Averag e	Very Low
Boarding time impact	Very Low	Very Low	High	Low	Low	High	Very Low	High	Averag e
Data Storage	Very High	High	Very Low	Low	Low	Very High	Very High	Very High	Very High
Ancillary revenues	Very High	High	High	Low	Average	Very High	Very High	Very High	Very Low
Safety	Very High	Very High	Very High	Low	Average	High	Very High	Very High	Very High

In addition to the advantages outlined above, these means of payment also allow a technological evolution for the case of some future need. The applications associated with these technologies are diverse and the use of some of these features in conjunction with the transport system is a trend.

When considering as a determinant the guarantee that the passenger can access any station of CPTM/Metrô-SP SP carrying only the value of the integral tariff practiced and nothing more, the option to use the Smart Card loses force, since it is necessary to make a card available to the passenger.

Such a card may be provided after a registration or anonymously, but in both cases, the free hulling of the carton in the issuing of the 1st way is quite acceptable, but once additional track emissions are required, the free supply proves impracticable.

Considering that the cost of making a Smart Card (US$ 1,50) is approximately 48 times higher than the operational costs (R$ 0,11), the issuance of a 2nd way should be charged and / or restricted in some way, under penalty of exponential increase in the costs related to its use. In this way, the charge for the new route becomes unavoidable, preventing that the access of the passenger is possible only with the value of the tariff practiced.

In this scenario, the use of QR Code is more recommended because printing a new code will not add any additional cost to the passenger. In addition, printing a code to the passenger is much faster than issuing a new card.

The contactless Smart Card and QR Code are the two technologies recommended to be used as alternatives to substitute the Edmonson Ticket, with greater indication for the use of the QR Code, since it has a lower implementation cost and for solving the issue of the eventual passenger service of the CPTM system and, therefore, be prepared to attend a passenger profile with the characteristics of the Edmonson Ticket passengers in CPTM/Metrô-SP SP.

1.5.6.1. Tests and research results of QR Code technology

In order to carry out a QR Code verification, a pilot program was implemented to access the CPTM through a non-QR Code trip, where a system was prepared for this purpose, i.e. no product was used in the market improvement to be implemented without major problems.

To keep the environment of testing were selected 6 stations through the next following:

- Sale of tickets Edmonson between 10 and 20% of the total payers;
- Low rate of use of blockades
- Modernized infrastructure
- Within the city of São Paulo to facilitate the displacements in case of failures
- Validation of Edmonson ticket in only one blockade, being this one was permanently accepting the other forms of validation.
- Tickets with QR Codes were issued at the station's ticket offices through a POS or a thermal printer;
- The printed codes have been updated only on the day of purchase and to the extent they were purchased;
- The on-line and real-time query of the quantitative sales and use of codes at each station;
- Time of sale of the travel right to the passenger less than equal to 10 seconds per passenger input capacity in 15 minutes per minute.
- The system must be developed in such a way that, in its full operation, the codes can be used in any season and any day.
- The application can also be used as a tool for storing data through the internet, through the mobile application, and also as a QR Codes sale through ATMs, in the stations.
- The duration of the test period should be 6 (six) months, from the beginning of the operation of the system in the first station.

These were selected as the main stations for the execution of the tests:

Table 9 - Start Dates and Stations Test

Lines	Station	Start Date
Line 10 - Turquesa	Tamanduatei	22/10/2016
Line 7 - Rubi	Vila Aurora	12/11/2016
Line 9 - Esmeralda	Autodromo	19/11/2016
Line 12 - Safira	USP LESTE	26/11/2016
Line 8 - Diamante	Lapa	03/12/2016
Line 11 - Coral	Dom Bosco	10/12/2016

And the printed codes contained the information requested for the test:

Figure 25 - QR Codes used on the test

QR Code tickets were printed out at the ticket office and a central server was available, which controlled the capture of sales and use data, which is responsible for generating, encrypting and managing billing information. To this end, the readers installed on the blockades shared the existing physical VBS (Smart Ticket Validators) communication infrastructure, dispensing with the need for additional facilities for this purpose.

The readers used in the blockades were of the 2D barcode scanner type (digital image capture cameras - Model LV 4500), which were adapted in each type of blockade, since the variety of blockades in the CPTM makes it impossible to adopt a standardized single solution.

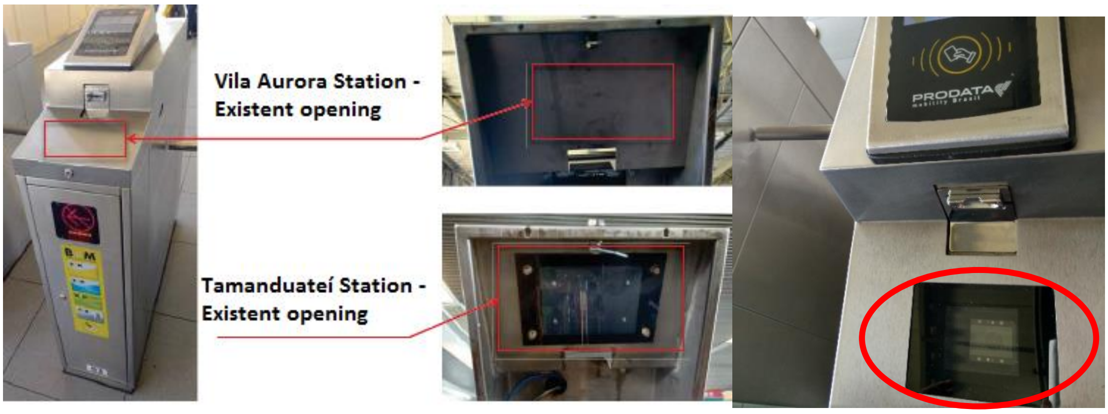


Figure 26 - Adopted solution for Vila Aurora and Tamanduatei stations

Ticket printing was performed by POS equipment (model VX 680), similar to debit and credit card machines, which printed the thermal paper codes, which were posted and delivered to passengers. Communication of this equipment with the system server occurred through data connection via GPRS (wireless).

Figure 27 - POS VX 680 unit used for tests

Also used was the DC 1000 equipment, together with a thermal printer, with data communication via Ethernet network.

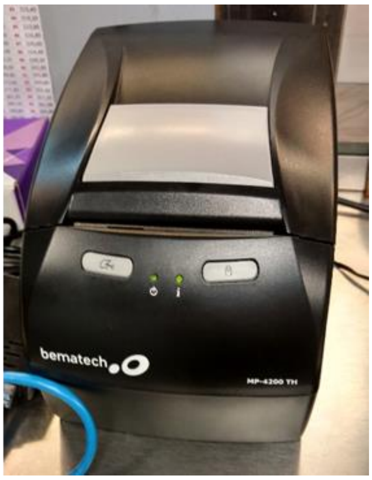


Figure 28 - DC 1000 and thermal printer used for selling and printing out the tickets with QR Code solution.

The employees received product, technical and operational training prior to the start of the operation at each station. In addition, operational manuals of the sales equipment (POSs) that were used to print the tickets were distributed.

All the stations that were part of the tests in this Pilot Program were duly signaled with visual communication materials installed at the ticket office and blockades, to divulge the QR Code. Folders were given to passengers with instructions to passengers.

Figure 29 - Instructions printed for passengers

1.5.6.1.1. TEST RESULTS

I. SALES AND VALIDATIONS OF TRAVEL RIGHTS

The results demonstrated that the bottleneck in the operation of this system was the selling process, not the validation process. The equipment used for the printing of the codes presented a great deal of instability in data communication, with constant variations of intensity and signal quality, which compromised the printing time of the codes (travel rights.

A new POS model, the Verifone VX 520, was tested which also printed on thermal paper, but used an Ethernet connection, which improved the result by 50%, but still needed to be improved.]The improvement of the process showed that there was an increase of time to highlight the ticket of the POS and to use a roll of thermal paper; the codes were made available with a natural curvature. POS technology has been replaced and the sale of travel rights has since been carried out by two devices, one tablet, with touch screen interface, for use by the operator together with a thermal printer (model MP 4200 TH), making the times become acceptable.

Table 10 - Time comparison

Process / POS and network connection	VX 680 and GPRS	Verifone VX 520 and Ethernet	Interface touch screen + thermal printer and Ethernet
Sales on Ticket office	22s	13s	8s
Printer QR Code	15s	8s	4s
Validation in blockades	1,5s	1,5s	1,5s

II. ISSUANCE OF REPORTS FOR SYSTEM CONTROL, MANAGEMENT AND AUDITING

As for the management reports, the system allowed the real-time reports to be carried out, with the following parameters:

- Sale by season, per operator and per period;
- Use by season and by period;
- Codes canceled, not used and due by station, operator and per period.

The characteristics of the technology and system tested allowed these reports also to provide a refinement of information obtained, such as: date and time of sale / use; start and end periods of validity of the code; identifier for each transaction performed; date and time at which the operator who made the sale.

Utilização QRCode

TIPO DE QRCODE: MULTIPLO,UNITARIO
SITUAÇÃO: CRÉDITO POR TIMEOUT,NÃO UTILIZADO,UTILIZADO,VENCIDO
LOJA: AUTODROMO,DOM BOSCO,LAPA L8,TAMANDUATEI,USP LESTE,VILA AURORA
DATA INICIAL: 16/10/2016 04:00
DATA FINAL: 01/04/2017 03:59

Unitário

Estação: TAMANDUATEI

ID QRCODE	IMPRESSÃO	VALIDADE INÍCIO	VALIDADE FIM	TRANSAÇÃO	QTD VENDIDA	QTD DISP	SITUAÇÃO	ÚLTIMA UTILIZAÇÃO
517	17/10/2016 16:03:27	17/10/2016 16:03:27	17/10/2016 23:59:59	1027	1	1	VENCIDO	
518	17/10/2016 17:28:26	17/10/2016 17:28:26	17/10/2016 23:59:59	1028	1	1	VENCIDO	
519	19/10/2016 12:19:53	19/10/2016 12:19:53	19/10/2016 23:59:59	1029	1	0	UTILIZADO	19/10/2016 14:35:10
521	19/10/2016 12:29:56	19/10/2016 12:29:56	19/10/2016 23:59:59	1031	1	0	UTILIZADO	19/10/2016 15:26:16
522	19/10/2016 13:02:10	19/10/2016 13:02:10	19/10/2016 23:59:59	1033	1	0	UTILIZADO	19/10/2016 15:24:35
522	19/10/2016 13:02:10	19/10/2016 13:02:10	19/10/2016 23:59:59	1033	1	0	UTILIZADO	19/10/2016 15:25:22
523	19/10/2016 13:02:41	19/10/2016 13:02:41	19/10/2016 23:59:59	1034	1	0	UTILIZADO	19/10/2016 15:25:50
524	19/10/2016 13:58:33	19/10/2016 13:58:33	19/10/2016 23:59:59	1035	1	0	UTILIZADO	19/10/2016 15:24:06
525	19/10/2016 13:59:03	19/10/2016 13:59:03	19/10/2016 23:59:59	1036	1	0	UTILIZADO	19/10/2016 14:34:20
526	20/10/2016 16:14:15	20/10/2016 16:14:15	20/10/2016 23:59:59	1044	1	1	VENCIDO	
527	21/10/2016 08:37:30	21/10/2016 08:37:30	21/10/2016 23:59:59	1045	1	1	VENCIDO	
528	21/10/2016 09:19:31	21/10/2016 09:19:31	21/10/2016 23:59:59	1046	1	1	VENCIDO	
529	21/10/2016 09:20:31	21/10/2016 09:20:31	21/10/2016 23:59:59	1047	1	1	VENCIDO	
530	21/10/2016 09:21:58	21/10/2016 09:21:58	21/10/2016 23:59:59	1048	1	1	VENCIDO	
531	21/10/2016 10:46:23	21/10/2016 10:46:23	21/10/2016 23:59:59	1049	1	0	UTILIZADO	21/10/2016 15:23:16
531	21/10/2016 10:46:23	21/10/2016 10:46:23	21/10/2016 23:59:59	1049	1	0	UTILIZADO	21/10/2016 15:23:59
531	21/10/2016 10:46:23	21/10/2016 10:46:23	21/10/2016 23:59:59	1049	1	0	UTILIZADO	21/10/2016 15:24:37
531	21/10/2016 10:46:23	21/10/2016 10:46:23	21/10/2016 23:59:59	1049	1	0	UTILIZADO	21/10/2016 15:25:26
532	21/10/2016 10:51:33	21/10/2016 10:51:33	21/10/2016 23:59:59	1050	1	1	VENCIDO	
533	21/10/2016 13:34:59	21/10/2016 13:34:59	21/10/2016 23:59:59	1051	1	1	VENCIDO	
535	21/10/2016 13:42:15	21/10/2016 13:42:15	21/10/2016 23:59:59	1053	1	0	UTILIZADO	21/10/2016 15:07:22
536	21/10/2016 13:58:48	21/10/2016 13:58:48	21/10/2016 23:59:59	1054	1	1	VENCIDO	
537	21/10/2016 13:59:01	21/10/2016 13:59:01	21/10/2016 23:59:59	1055	1	0	UTILIZADO	21/10/2016 15:19:09
540	21/10/2016 14:12:13	21/10/2016 14:12:13	21/10/2016 23:59:59	1065	1	1	VENCIDO	
542	21/10/2016 14:19:40	21/10/2016 14:19:40	21/10/2016 23:59:59	1071	1	1	VENCIDO	
543	21/10/2016 14:20:28	21/10/2016 14:20:28	21/10/2016 23:59:59	1072	1	1	VENCIDO	
544	21/10/2016 14:24:26	21/10/2016 14:24:26	21/10/2016 23:59:59	1073	1	1	VENCIDO	

Figure 30 - Report example from the control system

III. SALES NUMBERS AND USE OF THE QR CODE DURING THE PILOT PROGRAM

Considering that the validation of the QR Code occurred only in a single blockade of only one station of each CPTM line and that the system was sometimes inoperative due to adjustments or maintenance, the numbers presented were quite significant.

Table 11 - Validation results

Station	Start Date	Days in operation	Transactions Qty.	Daly transactions Avg.
Tamanduatei	22/10/2016	156	60066	385
Vila Aurora	12/11/2016	135	42361	314
Autodromo	19/11/2016	126	24746	196
USP LESTE	26/11/2016	119	17864	150
Lapa	03/12/2016	112	37067	331
Dom Bosco	10/12/2016	105	21395	204
Total		**156**	**203499**	**1580**

IV. FAULTS OCCURRED DURING SYSTEM OPERATION

During the Pilot Program some failures occurred in the ticket sales and validation processes. The majority of the failures occurred on the ticket sales process, either in the connection of the printing equipment with the server or in the operation of the equipment itself.

The occurrences related to the ticket validation process in the blockades were limited to 3% of the total number of failures, whereas only the connection failures of the ticket printing equipment with the central server represented 47% of the total.

The other faults were distributed in different occurrences related to the ticket sales process. After replacing the POS equipment with data communication via GPRS for equipment with connection via Ethernet network, the failures have decreased considerably, eliminating practically 100% of the problems of communication with the central server.

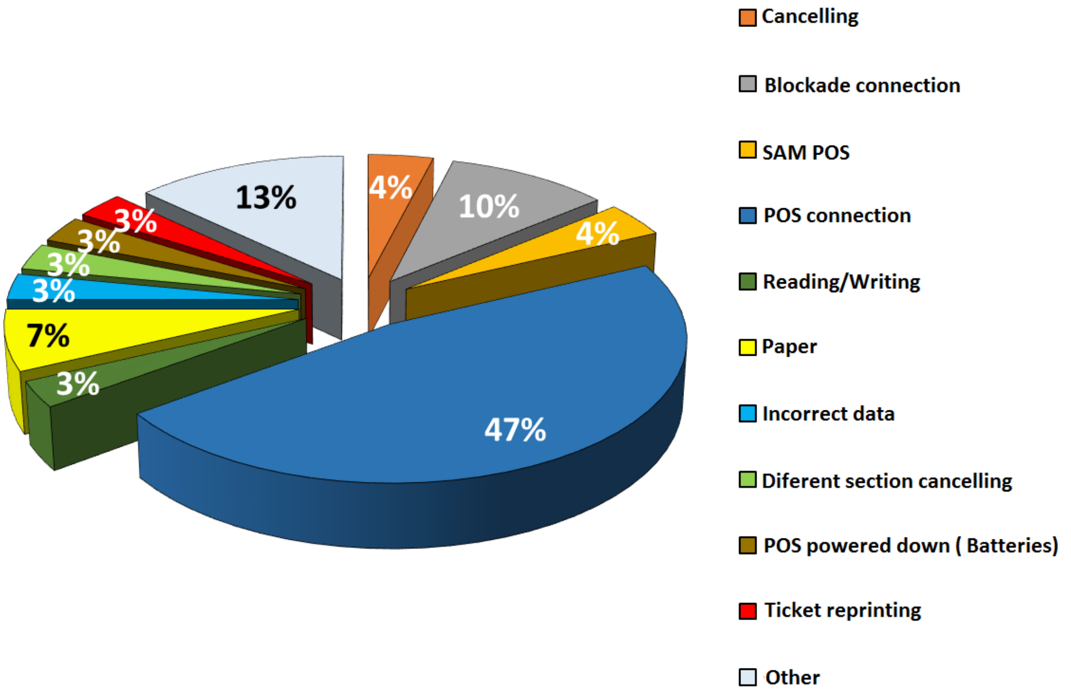


Figure 31- Failures per station

V. PERCEPTION OF THE PASSENGER

Considering that the validation time of the Edmonson Ticket in the blockades and its time of sale at the ticket office are considered as desired parameters, the maintenance of these operational characteristics (sale and validation) was fundamental to ensure that the routine of the passengers was not impacted.

In a survey carried out by CPTM between October and November 2016, we observed that there was good acceptance by the passengers, who did not demonstrate difficulties with the technology, and in some cases, passengers made a point of using the new ticket.

Passengers' opinions regarding reliability, ease of purchase, time of sale and validation, and suggested name of the ticket were requested.

The percentage distribution of passengers' opinions regarding the validation time in the blockades is shown in the chart below:

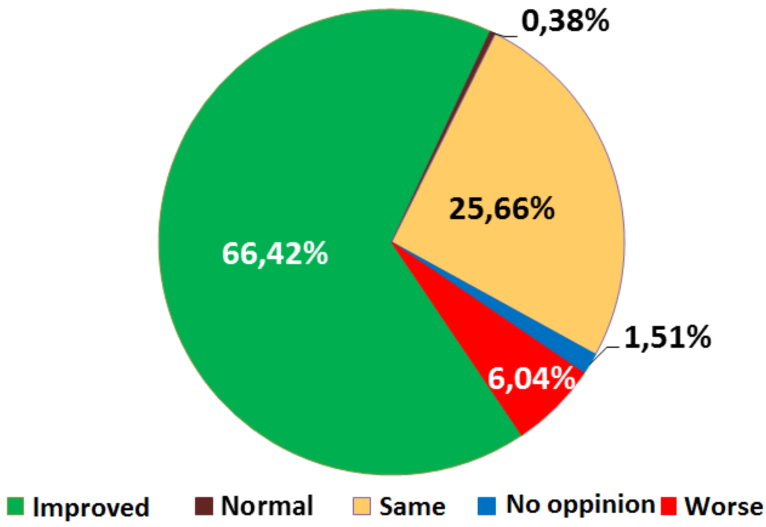


Figure 32 - Passenger opinion when comparing to Edmonson type – Time of operation

Approximately 94% of respondents stated that the validation time improved or remained the same as the Edmonson Ticket.

The percentage distribution of the passengers' opinion regarding the time of sale of the ticket right at the ticket office is shown in the following chart:

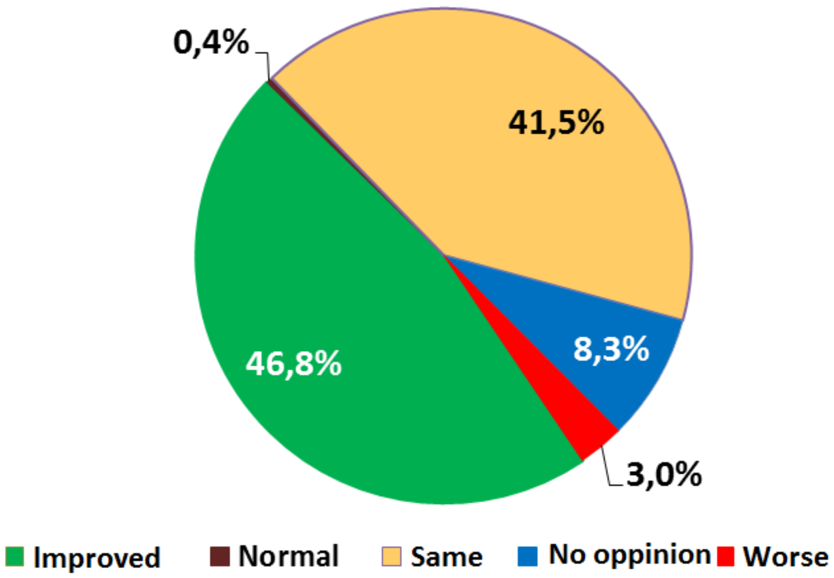


Figure 33 - Passenger opinion when comparing to Edmonson type – Time to buy the ticket

Approximately 88% of respondents stated that ticket sales time improved or stayed the same as the Edmonson Ticket.

The impact caused by routine passenger access to the stations was minimal, except for the moments of system instability, where the sales process took longer than usual.

VI. SECURITY LEVEL

The developed system showed the following security settings:

- Credits generated in each ticket (travel rights) had all their emissions and validations made by a SAM (Secure Access Module) module.

- The QR Code data structure was calculated by the SAM module, using 3Des encryption with symmetric 16-byte diversification key. In addition, each QR Code presented, as part of the data, a digital signature of at least 6 bytes, guaranteeing the integrity of the data.

- SAM module was incorporated with an "electronic signatures" in the transactions that, together with the digital signature contained in each ticket, had the purpose of making it impossible to create fraudulent credits in the system, giving higher levels of security and reliability.

- The generation of the QR Code credits and their use in the blockades were performed in online processes in order to guarantee the interconnection of all the equipment of the system and that the use of the credit is certified by the central server.

- In order to validate the security configuration adopted, several tests were carried out to verify the possibilities of fraud, such as: trying to validate an already used ticket or trying to validate the same ticket in different stations, at the same time, among others. In all tests, the system proved robust and did not allow the consolidation of fraud.

1.6. RISK ANALYSIS

1.6.1. RISK ASSESSMENT CONCEPT

All the activities of an organization involve risk. Organizations manage risk by identifying it, analyzing it and then assessing whether the risk should be modified by the risk treatment in order to meet to their risk criteria. Throughout this process, they communicate and consult stakeholders and monitor and critically analyze the risk and the controls that modify it, to ensure that no additional risk treatment is required. ABNT NBR ISO 31000: 2009 describes this systematic and logical process in detail.

Risk management can be applied to an entire organization, in its various areas and levels, at any time, as well as specific functions, activities and projects.

Risk is defined in ISO 31000 risk management as the effect of uncertainty on objectives; so, in a dependability context managing risk concerns the way in which uncertainty affects the dependability of systems and services. Risk can have positive consequences (effects of uncertainty may be positive as well as negative). Sources of potential benefit (opportunities) need to be managed as well as source of potential loss (threats). Uncertainty can involve lack of knowledge, inherent variability, ambiguity in language and understanding, indeterminacy, unpredictability, as well as the uncertainty inherent in complexity. Any of these forms of uncertainty are a source risk. One important form of risk is where potential events can be identified, and outcomes predicted. The uncertainty lies in whether and when an event will occur and in the magnitude of the outcome. It is possible to make a list of such risks and to prioritize them for action, for monitoring or allocating accountabilities. This is the process described in ISO 31000. However, there are other ways of considering risk that are particularly relevant to open systems. For example, there are situations where sources of risk can be envisaged but events and outcomes cannot be defined. Such sources of risk could be shortages of staff or poor morale or poor communications between different parts of a system. Often a combination of systemic problems interacts to cause failure. Although these are probably more accurately described as issues rather than risks, the result is still that there are uncertain consequences to objectives and dealing with such issues is part of assessing and managing risk.

Risk assessment is the overall process of risk identification, risk analysis and risk evaluation. Risks can be assessed at an organizational level, at a departmental level, for projects, individual activities or specific risks. Different tools and techniques may be appropriate indifferent contexts. Risk assessment provides an understanding of risks, their causes, consequences and their probabilities. This provides input to decisions about:

- whether an activity should be undertaken;
- how to maximize opportunities;
- whether risks need to be treated; choosing between options with different risks;
- prioritizing risk treatment options;
- The most appropriate selection of risk treatment strategies that will bring adverse risks to a tolerable level.

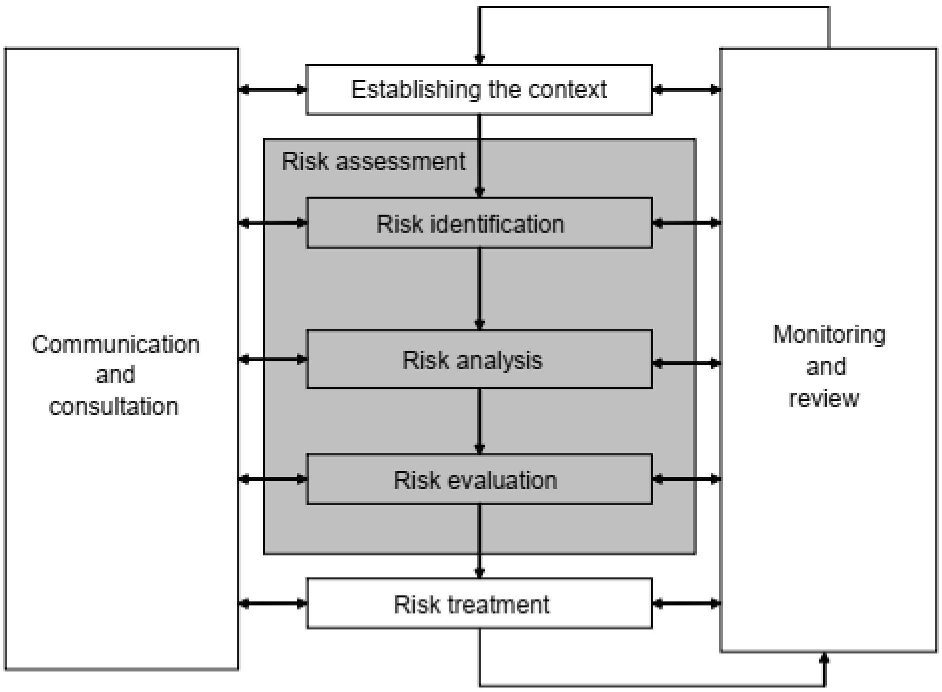


Figure 34 - Risk assessment process

Risk assessment provides decision-makers and responsible parties with an improved understanding of risks that could affect achievement of objectives, and the adequacy and effectiveness of controls already in place. This provides a basis for decisions about the most approach to be used to treat the risks. The output of risk assessment is an input to the decision-making processes of the organization.

The PMI-PMBOK® guide defines project risk is an uncertain event or condition that, if it occurs, will have a positive or negative effect on one or more project objectives, such as scope, schedule, cost, and quality.

Risk is not a fact, risk is not a process and risk is not a problem. Because it is a potential event, a risk should always be likely. Because it has an effect, a risk should always have an impact. The combination of probability and impact results in the criticality of the risk. Conceptually, the risk is different of the problem.

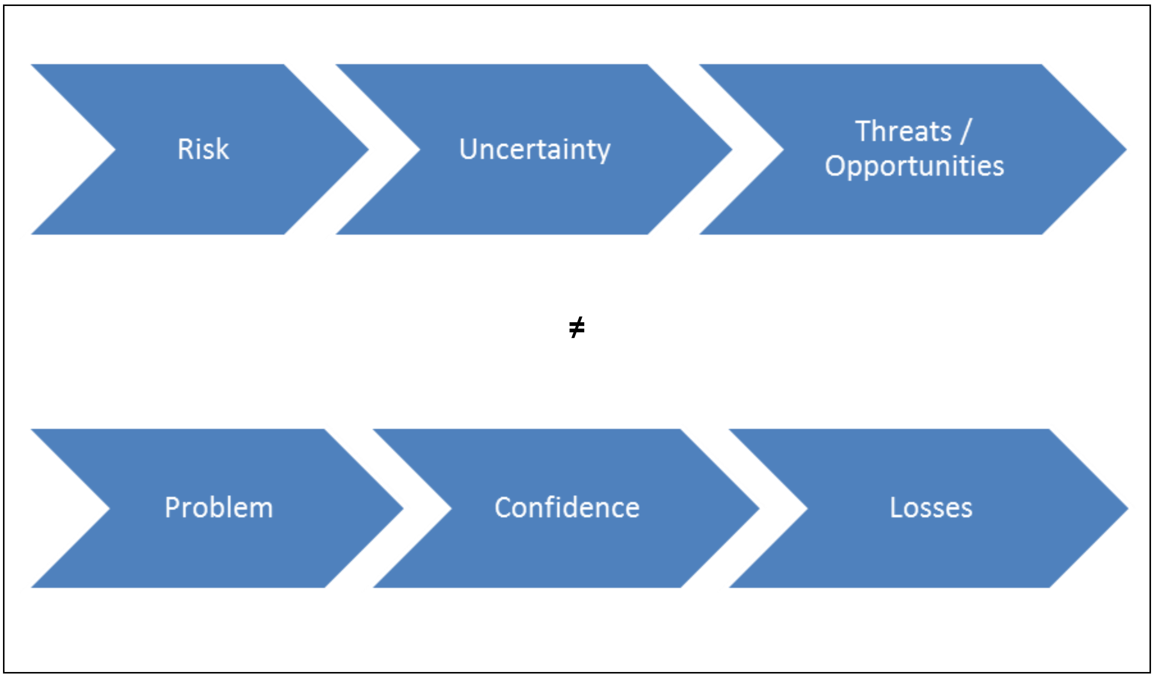


Figure 35- Risk x Problem

1.6.2. RISK ANALYSIS

A risk analysis must check the points that may come without presenting itself during the execution of a project or activity.

According ISO 31010:2009, risk analysis is about developing an understanding of the risk. It provides an input to risk assessment and to decisions about whether risks need to be treated and about the most appropriate treatment strategies and methods. Risk analysis consists of determining the consequences and their probabilities for identified risk events, considering the presence (or not) and the effectiveness of any existing controls. The consequences and their probabilities are then combined to determine a level of risk.

According to the PMO-PMBOK®, the goal of risk management is to increase the likelihood and impact of project opportunities (positive events) while reducing the likelihood and impact of project threats (negative events).

The term "risk" can be used to denote the result of the combination of the probability of occurrence of a given event and the impact coming from it. It should be noted that the definition of risk can also be associated with opportunities to increase the chances of success of the project, with positive effect on its objectives. The most common trend, however, is that the risk management process focuses only on the negative aspects of the concept.

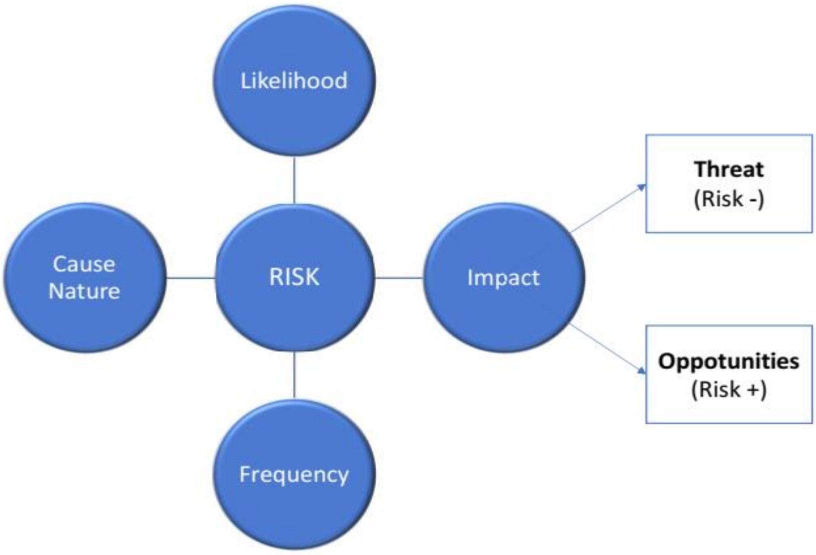


Figure 36 - Risks aspects

1.6.3. CHOICE OF THE RISK ASSESSMENT METHODOLOGY

ISO 31010:2009 has two sections. The first covers what is meant by risk and uncertainty, the benefits of using formal techniques, and how an understanding of risk is applied when making decisions. The second section describes the techniques. Annex A lists about 40 techniques and some of their characteristics (such as whether they are qualitative or quantitative and the expertise and effort needed to use them). In annex B, each technique is summarized in one page, with references given for further information.

For Cross, 2017, in open systems boundaries and responsibilities are unclear, no one has a complete understanding of the system which is complex and changing. An open system includes hardware, but people and software have an important role and people are in more complex ways as decision makers, rather only as operators as considered in the past. The consequences of open systems are less predictable, and probabilities are extremely difficult to estimate with any validity, so the process is most useful in an open system for short time scales and relatively closed subsystems. However, ISO31000 does not require the criterion to treat or not the level of risk.

It is the responsibility of the organization to set goals and responsibilities to achieve the objectives. Anything that can affect goals can be identified as a risk to be assessed. The ISO 31010 presents 40 techniques.

This project based in change a service that interact with the public (passengers) demands a technique for reporting and recording risks combining qualitative or semi-quantitative ratings of consequence and probability to produce a level of risk or risk rating.

According to the ISO 31000, a consequence/probability matrix is used to rank risks, sources of risk or risk treatments based on the level of risk. It is commonly used as a screening tool when many risks have been identified, for example to define which risks need further or more detailed analysis, which risks need treatment first, or which need to be referred to a higher level of management. It may also be used to select which risks need not be considered further at this time. This kind of risk matrix is also widely used to determine if a given risk is broadly acceptable, or not acceptable (see 5.4) according to the zone where it is located on the matrix.

The consequence/probability matrix may also be used to help communicate a common understanding for qualitative levels of risks across the organization. The way risk levels are set, and decision rules assigned to them should be aligned with the organization's risk appetite. A form of consequence/probability matrix is used for criticality analysis in FMECA or to set priorities following HAZOP. It may also be used in situations where there is insufficient data for detailed analysis, or the situation does not warrant the time and effort for a more quantitative analysis ratings of consequence and probability to produce a level of risk or risk rating.

The "probability and impact matrix" is a tool often used in the qualitative analysis of risks and, in a simplified way, allows them to be classified as low, medium or high priority. In effect, organizations can better deliver project performance by focusing on high-priority risks, which may require aggressive response strategies.

In a table "Applicability of tools used for risk assessment", ISO 31000 defines the consequence/probability matrix technique strongly applicable for:

- risk identification;
- risk analysis – consequence analysis;
- risk analysis – qualitative probability estimation;
- risk analysis – assessing the effectiveness of any existing controls;
- risk analysis – estimation the level of risk;
- Risk evaluation.

Use of the tool needs people (ideally a team) with relevant expertise and such data as is available to help in judgements of consequence and probability.

I. STAGES FOR THE PREPARATION OF THE RISK MATRIX

II. SWOT ANALYSIS

This stage should be conducted in an interactive and participative way and consists of the elaboration of a list of risks associated to the project. There are several ways of identifying and characterizing risks, such as holding brainstorming meetings, collecting expert opinion, or searching for historical information and knowledge accumulated in previous projects of a similar nature. The SWOT analysis was elaborated with the participation of the team responsible for the project object. All stakeholders were involved in the risk assessment step. This participation contributed to the elaboration of an analysis capable of reflecting the reality of the project.

Due care was taken to involve people with expertise, attitude and a clear understanding of the business culture, CPTM and Metrô-SP. SWOT Analysis technique were used as a critical review to identify expected limitations, obstacles and misuse scenarios of the QR Code project.

Firstly it's developed a SWOT Analysis Framework (See Appendix B), which show the strengths and weaknesses (internal factors) plus opportunities and threats (external factors)

Secondly it's built a table to help in the Cross-SWOT design (See Appendix C), This framework is a derivation of SWOT analysis, in which the factors are combined seeking for enhancement (when both are positive or negative) between them or annulment (when one is positive and another negative). As the objective of verifying the identified situation before classifying it as risk, the crossed SWOT was carried out in order to establish a cause and effect relationship.

The result is described on the table below:

Table 12 - Analysis of internal and external factors

SWOT		Analysis of external factor	
		Opportunities	**Threats**
Analysis of internal factor	Strennght	- The new system reduce the cost of the process chain of the ticketing system, reducing low deployment, operation and maintenance costs; - Build partnership though external ticket office; - Customer interaction encourages sales; - Less time to buy tickets (smaller lines) and to access the embark platform, the validation method is without physical contact; - Sharing the system with other services can provide non-fare revenues; - Expertise for the project available in the national market and commercial partners available for field-testing and implementing technology; - High level of security reduces losses due to the fraud; - Risk of revenue loss under responsibility of company hired to manage QR Code ticket sale; - A reliable system can reduce revenue loss due to fraud; - Easy of getting partners for field-testing with passengers.	- Concessions law may be used to allow a contract longer than five years, so that the management cost during the transition period between contract reduces; - Digital platform and sales by app can reduce the waste paper tickets; - Network and servers infrastructure (means more cost) ensures appropriated information of the transport system storage; - Although the lack of experience, the technology is widely used in other segments around the word; - Hiring process inside the country is easier than hiring outside, according to the Brazilian bidding laws; - The companies are pioneer in the implementation of new systems or technologies that involve public use; - More passengers on the platform demand to increase security for boarding and also may demand headway evaluation and also worsen the customer satisfaction index and affect internal indicators.
	Weakness	- Concessions law may be used to allow a contract longer than five years, so that the management cost during the transition period between contract reduces; - Digital platform and sales by app can reduce the waste paper tickets; - Network and servers infrastructure (means more cost) ensures appropriated information in the transport system storage; - Although the lack of experience, the technology is widely used in other segments around the word; - Hiring process inside the country is easier than hiring outside, according to the Brazilian bidding laws; - More passengers on the platform demand to increase security for boarding and also may demand headway evaluation and also worsen the customer satisfaction index and affect internal indicators.	- Difficulty in implementing the new technology with its own infrastructure can cause internet service quality; - Contingency plan for the sales tickets in case of breach of contract every 5 years, because Law of bidding does not allow contract greater than five years; - Equipment obsolescence plus high number of turnstiles failures due the Edmonson technology can influence on the operation cost, company image; - Transition period to implement the new technology can delay or obstruct the revenues receiving; - Bidding process can not be late the hiring; - The unavailability of the technology leads to the use of other more expensive payment methods, but without stopping; - Possibility of reversing dismissals in court.

This matrix is the key determinants of what action plans will be developed to put our strategies development therefore it is shown the 4 types of strategies:

a) Offensive Strategies: Strengths x Opportunities (SO)

In these strategies, a positive internal factor (Strengths) combined with a favorable external factor (Opportunities), bring to a favorable situation occurrence.

- The new system reduce the cost of the process chain of the ticketing system, reducing low deployment, operation and maintenance costs: if you compare to Edmonson maintenance, QR Code system doesn't have physical parts, the automation reduce the sales process and the deployment can use part of the existent infrastructure;

- Build partnership though external ticket office: can reduce operation cost through the distribution of the sales service and relocation of labor force;

- Customer interaction encourages sales: the facility to buy the ticket through a mobile, encourages the customer to use this service;

- Less time to buy tickets (smaller lines) and to access the embark platform, the validation method is without physical contact: the sales process and validation process is faster than the others process;

- Sharing the system with other services can provide non fare revenues: The possibility of share others services, the customer can buy complementary services to solve the last mile problem;

- Expertise for the project available in the national market and commercial partners available for field testing and implementing technology: the used of QR Code technology is in expansion;

- High level of security reduces losses due to the fraud: the amount of information that the QR Code ticket that concentrates and a robust system, with encryption, reduce the fraud;

- Risk of revenue loss under responsibility of company hired to manage QR Code ticket sale: all the operation responsibility (including fraud risk) is transferred to an outsourcing company;

- Easy of getting partners for field-testing with passengers: the system implementation in the existent systems is not complex.

b) Confrontation Strategy: Strengths x Threats (ST)

It is also considered an adjust strategy where we use our strengths in order to be able to overcome and neutralize the threats.

- The cost of the process chain of the ticketing system is low comparing to Edmonson technology: Edmonson tickets has a high production cost and the equipment high maintenance cost, moreover with the QR Code operation automation reduce the need for workers. Therefore the project implementation requires investments;

- Automation/Network system can generate hacking and hackers invasion: it’s necessary invest in IT technology;

- Reducing employees (due automation) can result in union protest and reversing layoffs by the court: the automation can reduce cost but in contrast it can result on legal defense expenditures;

- The more profitable sale method (QR Code) under external control: This ticket method without logistic expenditures is more profitable however the control of the system is in the outsourcing company hands, KPI is important to measure the service quality;

- Obsolescence is the responsibility of the company that manages the market system, as well as its updating: it can increases spending;

- The companies are pioneer in the implementation of new systems or technologies that involve public use: CPTM and Metrô-SP-SP have expertise in public behavior changing, but it will be a challenge to influence passengers using a new technology;

c) Strengthening Strategy: Weaknesses x Opportunities (WO)

The reinforcement strategy comes up whenever you need to think about how to lessen the impacts that a weakness of your business has by decreasing the chance of an opportunity occurring. The actions taken should reinforce their weaknesses so that they do not interfere in their external environment.

- Concessions law may be used to allow a contract longer than five years, so that the management cost during the transition period between contract reduces: the risk of contract disruption must be considered;

- Digital platform and sales by app can reduce the waste paper tickets: the paper tickets can generate an environmental problem;

- Network and servers infrastructure (means more cost) ensures appropriated information in the transport system storage: the opportunity to get more passengers data (for strategic plans) means more cost;

- Although the lack of experience, the technology is widely used in other segments around the word: it’s an opportunity to get know-how, in the contract must include a condition to transfer knowledge;

- Hiring process inside the country is easier than hiring outside, according to the Brazilian bidding laws: it can delay the bidding, but it’s important to build a solid specification to the bidding. Moreover domestic market is easier to obtain commercial partners;

- More passengers on the platform demand to increase security for boarding and also may demand headway evaluation and also worsen the customer satisfaction index and affect internal indicators: Although the passenger rate increased, it’s important to use the passenger data storage to adjust the operation system, headway, etc.

d) Defense Strategy: Weaknesses x Threats (WT)

Finally, the last type of strategy is defensive, where you will be in the most critical scenario and that aims to minimize losses and negative impacts that weaknesses and threats can cause in your company. The idea here is to think about how to minimize the chance of a weakness to make a threat come true.

- Difficulty in implementing the new technology with its own infrastructure can cause internet service quality: it's important to evaluate the current infrastructure for each location/company for basic project elaboration;

- Contingency plan for the sales tickets in case of breach of contract every 5 years, because Law of bidding does not allow contract greater than five years: it means increase the expenditures;

- Transition period to implement the new technology can delay or obstruct the revenues receiving: it's important a solid execution schedule and continuous inspection;

- Bidding process cannot be late the hiring: in special after the end of the first contract, to avoid contingence plans;

- The unavailability of the technology leads to the use of other more expensive payment methods, but without stopping: the technology monopoly and dependence can affect the cost operation, contingence plans must be implemented;

- Possibility of reversing dismissals in court: one of the project consequences is the workers´ reduction, it can result on legal defense expenditures;

e) Strategy and operative objectives

Finally, under the evaluation above, we found some strategies:

- Change mechanical tickets to virtual tickets in all stations;

- Improve revenue, reducing the intermediation by other payments means;

- The basic and execution project must be solid for the bidding and contemplate all the interferences;

- Implementation in parts, keeping the mechanical ticket until the last station in 36 months;

- During the transition, it must have a solid execution schedule and continuous field inspection;

- Contingence plans in case of failures, contract disruption or delay in new contracts;

- Reallocation of employees for other operational tasks and coverage of scales;

- The passenger data acquired by the system must be used to control the operation flow, headway, etc.

- It's important to make KPIs to measure the service quality provided by the company who is responsible to run the system;

- Create projects to attract the customer (passenger) to use this new technology;

III. IDENTIFICATION OF THE MAIN RISK

After the SWOT step, cross-SWOT analysis and expert team analysis, the risks were defined. The following table presents an extract containing 11 of the 36 risks listed in APPENDIX A.

Table 13 - Partial Risk Table

ID	RISKS
R1	If tariff policy depends on the Government, the budget can be affected.
R2	If the process of ticketing and validation by QR Code is faster, the time spent in the lines to buy tickets and access the paid area will be reduced.
R3	If QR Code is copyright-free, the Companies don't have to pay rights or license.
R4	If demand information is available in the QR Code system, Companies can effectively manage the operation of the stations.
R5	If both companies offer different payment methods, the payment system has a contingent means.
R6	If QR Code is used on a large scale, absenteeism due to repetitive strain injuries from ticket office employees will be reduced.
R7	If the new system reduces the cost of the ticketing process chain, deployment, operation and maintenance costs tend to be low.
R8	If It built partnership though external ticket office, it is possible relocate ticket office employees in other areas.
R9	If QR Code system allows more customer interaction, it will be possible encourage sales by digital platform and apps.
R10	If the non-contact validation method is successful, passengers will take less time to buy tickets (smaller lines) and to access the embark platform.
R11	If the system is shared with other services, it will be able to provide non-fare revenues.
. . .	. . .

IV. QUALITATIVE DEFINITION

In this step it is necessary, from a careful analysis, to assign the respective weight to each risk previously listed in relation to the probability of occurrence of the event and its impact on the project objectives, according to the parameters outlined in the following tables.

Table 14 - Event Likelihood

EVENT LIKELYHOOD		
Qualitative Definition	**Context**	**Weight**
Very high	Expected occurrence	**0,90**
High	Very likely to occur	**0,70**
Medium	Occasional	**0,50**
Low	Unlikely to occur	**0,30**
Very Low	Very unlikely to occur	**0,10**

Table 15 - Impact on Project Objectives

IMPACT ON PROJECT OBJECTIVES					
	Very Low 0,05	**Low 0,10**	**Moderated 0,20**	**High 0,40**	**Very High 0,80**
Project Objectives	Imperceptible effect in achieving the defined objectives	Slight effect on the achievement of the established objectives	Difficulty in achieving the stated objectives	Deep impact the achievement of established objectives	It avoids achieving the goals established

It should be noted that the qualitative analysis of the risks must be constantly reviewed and the degree of probability of occurrence as well as its impact on the results can be modified throughout the life cycle of the project.

V. CALCULATION OF CRITICITY (P X I)

Specific combinations of probability and impact - which can cause a risk to be classified as of high, moderate or low importance - give rise to the matrix itself. In this tool, the values (weights) assigned to each track are multiplied, giving rise to five large areas: red (with the highest numbers) to light green gray (with the lowest numbers).

Table 16 - Likelihood x Impact

LIKELIHOOD		THREATS					OPPORTUNITIES				
80 - 99%	0,9	0,05	0,09	0,18	0,36	0,72	0,72	0,36	0,18	0,09	0,05
60 - 80%	0,7	0,04	0,07	0,14	0,28	0,56	0,56	0,28	0,14	0,07	0,04
40 - 60%	0,5	0,03	0,05	0,1	0,2	0,4	0,4	0,2	0,1	0,05	0,03
20 - 39%	0,3	0,02	0,03	0,06	0,12	0,24	0,24	0,12	0,06	0,03	0,02
0 - 19%	0,1	0,01	0,01	0,02	0,04	0,08	0,08	0,04	0,02	0,01	0,01
Impact		**0,05**	**0,1**	**0,2**	**0,4**	**0,8**	**0,8**	**0,4**	**0,2**	**0,1**	**0,05**

The result of the combination of likelihood and impact allows to compare the risks raised, being possible to identify those with greater potential harmful to the project.

VI. TREATMENT OF RISKS

Risk response planning indicates possible actions that can be taken to reduce the vulnerabilities found in the project. The types of responses can be verified in the following table.

Table 17 - Risks treatment

NON-ACCEPTANCE OF RISKS
Avoiding Risk: change in the project plan
Transfer of Risk is to change the consequence of a risk with a third party
ACCEPTANCE OF RISKS
Monitoring: accompanies the variation in the likelihood of occurrence of the risk
Mitigation: seeks to reduce the likelihood and / or consequence of an adverse event to an acceptable threshold
Contingency: it acts in the reduction of the impacts of the risks

The choice of the response to be made will depend on the criticality of the risk, being indicated for low risk cases actions such as avoidance and / or monitoring; for moderate risks, contingency and mitigation (when the cost of this action is reduced) and for high risks, mitigation and contingency.

Risk management must take place throughout the project life cycle in order to monitor identified risks, monitor residual risks, identify new risks, implement risk response plans and assess their effectiveness.

1.6.4. RESULT ANALYSIS

The experts brought the uncertainties that can impact the performance of the project (term, cost, quality). There was consultation with all stakeholders. The SWOT analysis may have its flexibility bias with risk of loss of objectivity, however, driving in a clear and objective manner, with steps such as cross-SWOT before issuing the risk statement kept the focus on the project.

Objective is not and was not to find guilty but to anticipate the problems, treat them and make feasible the project. Based on the concept of risk presented in figure 2, people should have the clarity that the job consists in presenting bad news but not surprises. People must present probabilities of events, not facts. The goal is to think of all possible risks before they become a problem. With related risks, the group followed for risk analysis based on the impact x likelihood table, according to IEC ISO 31010.

Evaluations were made based on experience in order to measure likelihood and risk. For the unknown risks, the work was done around the perceptions about the variables and even a real experience with the passengers. The main objective was to decrease the chance of error based on the estimates and prioritize the risks with the greatest impact.

Table 18 - Risk Matrix

The above risk matrix represents all risks related and treated based on the impact table x likelihood. The detailed table containing the analysis of all the risks is in Appendix A.

According to the risk matrix, risk ID 3 is the one that was analyzed as a major treatment priority. Interestingly, it was rated as an opportunity and without threat. Based on the analysis of this risk, the QR Code is a technology of public domain; therefore, it is an opportunity of not having to pay the license or rights. In this case, the action plan is the acceptance of the risk.

Risk 26 is a threat that deals with the security of the IT system and the possibility of attempted hacking. It was analyzed and classified as very likely to occur and very high impact if occurs. The action plan is to avoid risk by implementing IT security policies together with the project.

It is a fact that the risk matrix has the bias of analyzing threats. However, due to the project's adherence to the needs of the Companies, of 36 risks analyzed, only 16 were classified as threats.

The next step is treating all risks based an action plan according to the instructions for acceptance or non-acceptance of the risks. According to the PMO-PMBOK®, periodic meetings should take place with the tactical (monthly) and operational (weekly) levels, as well as visits in the areas involved to understand the routine and follow the information obtained. The "manager's hand" to keep the focus is that counts in the end.

1.7. FINANCIAL PLAN

1.7.1. COST COMPARISON

The costs related to the operation of different types of tickets used for passenger´s access to CPTM stations are different, which cause different impacts on CPTM revenues. In the process of measuring the costs associated with the use of a certain type of ticket, it is essential to consider direct and indirect costs.

For the figures of direct costs, we must consider essentially the amounts spent on operating and maintenance personnel, acquisition of the properly tickets, transport of values, security etc. For indirect costs, it was considered the expenses with personnel to carry out the management of the system, operation (cashiers), cleaning, etc.

The following table presents the average cost per trip relative to the use of each type of ticket / card in CPTM's ticketing system (what is proportionally the same for METRÔ-SP SP), taking into account the monthly average numbers of the year of 2017.

Table 19 - Average cost per trip

AVERAGE CHAIN COSTS PER TICKET										
		EDMONSON		BU		BOM		OTHERS		AVERAGE / MONTH
DIRECT COSTS	R$	4.823.843,49	R$	2.368.362,00	R$	600.000,00			R$	7.792.205,49
INDIRECT COSTS	R$	84.908,11	R$	22.972,88	R$	11.486,44	R$	5.743,22	R$	125.110,66
TOTAL OF COSTS	**R$**	**4.908.751,60**	**R$**	**2.391.334,88**	**R$**	**611.486,44**	**R$**	**5.743,22**	**R$**	**7.917.316,15**
AMOUNT OF JOURNEYS	**R$**	**7.908.204,00**	**R$**	**19.624.424,00**	**R$**	**4.653.707,00**	**R$**	**275.708,00**	**R$**	**32.462.114,00**
AVERAGE COST PER JOURNEY	**R$**	**0,62**	**R$**	**0,12**	**R$**	**0,13**	**R$**	**0,02**	**R$**	**0,24**

As shown in the table above, Edmonson's entire chain costs are considerably higher than any other technology used. However, since it is an internal ticketing system, Edmonson represents the highest net revenue for both CPTM and METRÔ-SP SP once there is no sharing rule associated with this modality.

Table 20 - Net revenue per ticket

NET REVENUE PER TICKET										
		EDMONSON		BU		BOM		OTHERS		AVERAGE / MONTH
TICKET REVENUE	R$	30.051.173,30	R$	68.278.805,03	R$	16.460.663,61	R$	945.974,87	R$	115.736.616,81
LOSSES			-R$	12.620.935,21	-R$	2.786.940,06			-R$	15.407.875,27
NET TICKET REVENUE	R$	30.051.173,30	R$	55.657.869,82	R$	13.673.723,55	R$	945.974,87	R$	100.328.741,54
% PARTICIPATION		30,0%		55,5%		13,6%		0,9%		100,0%
NET REVENUE PER PAYED JOURNEY	R$	3,80	R$	2,84	R$	2,94	R$	3,43	R$	3,09

The data used to determine the costs per trip were based on CPTM's numbers. Therefore, due to the similarity of the operators (the same metropolitan region, the same ticket price, the same system and generally the same client's profile) it was assumed for financial viability purposes the same parameters. Evidently, the differences between demands, number of stations and so on was proportionally considered for elaboration of the analysis.

1.7.2. BUSINESS MODEL

1.7.2.1. GENERAL ASSUMPTIONS

The business model assumes a partial replacement of the ticket office with automatic machines, which results in a decrease in personnel costs. In addition, it is planned to deploy a mobile app for ticket sales as well as a web platform.

The business model is based on a service contract for a period of 5 years (to comply with Brazilian regulations for public companies) in which the provider must allocate the ATMs, carry out the installation of all necessary equipment and infrastructure as well as maintain the whole technological park.

Thus, CAPEX is composed of:

- QR Code Validators
- ATMs
- Ticketing system (software and hardware)
- APP mobile
- Web Platform
- Infrastructure

Operating costs (OPEX) were estimated based on internal parameters and consider the following items:

- Personnel;
- Ticket production (QR Code)
- Back office
- Web Links
- Operation assignments
- Maintenance assignments

1.7.2.2. BUDGETING METHOD

The budgeting process was carried out through detailing all components and costs involved in the contract – so called unit cost composition, which resulted in a technical specification that was sent to market players for valuation. The received proposals were analyzed item by item in order to extracted information to create the most affordable financial model for the companies.

The budgeting process takes into account the implementation phases as well as the amortization and depreciation of the invested capital. In the spreadsheets is also included all costs inherent to human resources involved in installation, operation and maintenance during the term of the contract.

1.7.2.3. FINANCIAL ASSUMPTIONS

In order to estimate the cost of contracting this service, it was used the discounted cash flow method from the perspective of the service provider. All costs extracted from the budgeting phase were included as well as taxes and fees related to the Brazilian regulations applied to this case.

To determine the contract costs for both CPTM and METRÔ-SP SP the simulations sought to achieve the IRR exactly equals the expected WACC so that the provider can be properly remunerated to cover both its operational costs (OPEX) and the investment made (CAPEX). The analyzes were based on simulate different revenues to the provider which is understood as the cost of the contract or the amount of money that CPTM and METRÔ-SP SP will have to spend monthly to afford this service. For this, the adopted WACC was **6.84%** yearly considering part of the invested capital captured under subsidized rates in fomentation banks.

The results obtained in the financial models will support the project approvals internally in the companies as well as the bidding process itself.

1.7.2.4. BUSINESS CASE 1 – CPTM

The implementation strategy at CPTM was developed in a gradual manner so that passengers can adapt to the new ticketing system and according to the physical schedule for installation of required equipment and infrastructure. These assumptions reflect directly in the financial model once the capital expenditure CAPEX must be considered in the timeline during the elaboration of the cash flow.

The implementation will start in Line 13. The choice to start from this line is based on the possibility of mitigating the initial risks of the project in an environment of lower demand. This is a new line with only 3 stations with the best and newest infrastructure in the entire CPTM's network.

After Line 13 approval, the deployment will follow in pairs of lines as shown in the table below:

Table 21- CAPEX participation per line - CPTM

LINE	CAPEX PARTICIPATION	ESTIMATED TIME
13	5%	3 months
11 / 12	27%	5 months
7 / 10	31%	5 months
8 / 9	37%	5 months

In each line must be available a minimum amount of sales machine and validators that was determined in order to meet current and expected demand for the next 5 years – the duration of the contract.

Table 22 - Participation divided by equipment - CPTM

Equipment	Line 7	Line 8	Line 9	Line 10	Line 11	Line 12	Line 13	TOTAL
ATM Debit / Credit	17	23	16	16	18	11	5	106
ATM Cash	25	35	25	24	26	16	8	159
POS / Tablet	42	71	39	52	57	28	18	307
Validator	93	126	88	88	99	60	27	581
Participation %	**15%**	**22%**	**15%**	**16%**	**17%**	**10%**	**5%**	**1153**

The operational costs OPEX must follow the contract implementation schedule proportionally and will be represented in the cash flow accordingly. Therefore, the contract payment will also be proportional to the implementation and will only reach the maximum value when all lines and stations are fully operating.

Table 23 - Cash Flow for 5 years - CPTM

CASH FLOW - COST OF CONTRACT DETERMINATION

	Year 1	Year 2	Year 3	Year 4	Year 5
(+) Operational Revenus	R$ 2.897.317,34	R$ 18.265.027,08	R$ 23.160.757,90	R$ 23.160.757,90	R$ 23.160.757,90
(-) Operational Expenses	R$ 1.436.753,31	R$ 9.630.706,36	R$ 12.085.461,86	R$ 12.085.461,86	R$ 12.085.461,86
(=) EBITDA	R$ 1.460.564,02	R$ 8.634.320,71	R$ 11.075.296,04	R$ 11.075.296,04	R$ 11.075.296,04
(-) Depreciation	R$ -	R$ 935.909,69	R$ 1.659.311,50	R$ 1.659.311,50	R$ 1.659.311,50
(=) EBIT	R$ 1.460.564,02	R$ 7.698.411,02	R$ 9.415.984,54	R$ 9.415.984,54	R$ 9.415.984,54
(-) Interest and Taxes	R$ 373.443,04	R$ 2.547.622,61	R$ 3.222.314,38	R$ 3.222.314,38	R$ 3.222.314,38
(=) Net Profit	R$ 1.087.120,98	R$ 5.150.788,41	R$ 6.193.670,16	R$ 6.193.670,16	R$ 6.193.670,16
(+) Depreciation	R$ -	R$ 935.909,69	R$ 1.659.311,50	R$ 1.659.311,50	R$ 1.659.311,50
(=) Operational Cash Flow	R$ 1.087.120,98	R$ 6.086.698,11	R$ 7.852.981,66	R$ 7.852.981,66	R$ 7.852.981,66
(-) Investiments	R$ 19.359.096,92	R$ 7.234.018,08	R$ -	R$ -	R$ -
(=) NET CASH FLOW	**-R$ 18.271.975,94**	**-R$ 1.147.319,97**	**R$ 7.852.981,66**	**R$ 7.852.981,66**	**R$ 7.852.981,66**

The simplified cash flow is intended to demonstrate the main components considered in the financial evaluation to determine the cost of the contract.

It is worth saying that the net present value was intentionally designed to result in a zero value, since this indicates that the capital remuneration established through the WACC was fully attained

1.7.2.4.1. VALUE FOR MONEY

Finally, the value for money analyses took into consideration the transition strategy, where the costs of the current billing system were proportionally inserted. Thus, it considers that those employees involved in ticketing activities are reallocated in other operational activities where there is a need for hiring.

Therefore, the tables below show the total cost of the billing activity for the next 5 years from two perspectives:

a) Considering the proposed new system

Table 24 - Value for money / Strategy 1 - CPTM

	Year 1	Year 2	Year 3	Year 4	Year 5
Costs of current system	52.849.772,79	35.336.153,09	20.191.024,32	20.191.024,32	20.191.024,32
Costs of new system	R$ 2.897.317,34	R$ 18.265.027,08	R$ 23.160.757,90	R$ 23.160.757,90	R$ 23.160.757,90
Total Costs	R$ 55.747.090,13	R$ 53.601.180,16	R$ 43.351.782,22	R$ 43.351.782,22	R$ 43.351.782,22
Total accumulated	**R$ 55.747.090,13**	**R$ 109.348.270,29**	**R$ 152.700.052,51**	**R$ 196.051.834,73**	**R$ 239.403.616,95**

b) Keeping the current system

Table 25 - Value for money / Strategy 2 - CPTM

	Year 1	Year 2	Year 3	Year 4	Year 5
Costs of current system	57.688.640,92	57.688.640,92	57.688.640,92	57.688.640,92	57.688.640,92
Total accumulated	**R$ 57.688.640,92**	**R$ 115.377.281,84**	**R$ 173.065.922,76**	**R$ 230.754.563,68**	**R$ 288.443.204,60**

Figures show that over the next 5 years the ticketing system through QRCODE will represent a saving of R$ 49.039.587,65 for CPTM.

1.7.2.5. BUSINESS CASE 2 – METRÔ-SP SP

The deployment strategy for METRÔ-SP SP will also follow the principle of starting from the line with de smallest movement in terms of demand and then it will cover the others.

Once approved the implementation in Line 15 (the first), the other lines will follow the schedule bellow.

Table 26 - CAPEX participation per line – METRÔ-SP SP

LINE	CAPEX PARTICIPATION	ESTIMATED TIME
15	6%	3 months
3	22%	4 months
1 / 2	43%	5 months
4	12%	3 months
5	17%	3 months

In each line must be available a minimum amount of sales machine and validators that was determined in order to meet current and expected demand for the next 5 years – the duration of the contract.

It is worth saying that although some of the METRÔ-SP SP lines are subject of concessions, the rules of ticketing activities are still in charge of METRÔ-SP SP itself, so that those lines are being considered in this analyzes.

Table 27 - Participation divided by equipment – METRÔ-SP SP

Equipment	Line 1	Line 2	Line 3	Line 4	Line 5	Line 15	TOTAL
ATM Debit / Credit	47	21	35	19	27	10	159
ATM Cash	71	31	53	28	40	15	239
POS / Tablet	138	60	102	54	78	30	461
Validator	260	113	192	102	147	57	872
Participation %	**30%**	**13%**	**22%**	**12%**	**17%**	**6%**	**1.730**

The operational costs OPEX must follow the contract implementation schedule proportionally and will be represented in the cash flow accordingly. Therefore, the contract payment will also be proportional to the implementation and will only reach the maximum value when all lines and stations are fully operating.

Table 28 - Cash Flow for 5 years – METRÔ-SP SP

CASH FLOW - COST OF CONTRACT DETERMINATION

	Year 1	Year 2	Year 3	Year 4	Year 5
(+) Operational Revenus	R$ 3.322.975,20	R$ 20.948.424,01	R$ 26.563.408,57	R$ 26.563.408,57	R$ 26.563.408,57
(-) Operational Expenses	R$ 1.846.228,01	R$ 12.375.457,68	R$ 15.529.818,49	R$ 15.529.818,49	R$ 15.529.818,49
(=) EBITDA	R$ 1.476.747,20	R$ 8.572.966,34	R$ 11.033.590,09	R$ 11.033.590,09	R$ 11.033.590,09
(-) Depreciation	R$ -	R$ 1.766.227,21	R$ 2.487.643,95	R$ 2.487.643,95	R$ 2.487.643,95
(=) EBIT	R$ 1.476.747,20	R$ 6.806.739,13	R$ 8.545.946,13	R$ 8.545.946,13	R$ 8.545.946,13
(-) Interest and Taxes	R$ 428.307,23	R$ 2.921.905,26	R$ 3.695.719,02	R$ 3.695.719,02	R$ 3.695.719,02
(=) Net Profit	R$ 1.048.439,96	R$ 3.884.833,87	R$ 4.850.227,11	R$ 4.850.227,11	R$ 4.850.227,11
(+) Depreciation	R$ -	R$ 1.766.227,21	R$ 2.487.643,95	R$ 2.487.643,95	R$ 2.487.643,95
(=) Operational Cash Flow	R$ 1.048.439,96	R$ 5.651.061,08	R$ 7.337.871,06	R$ 7.337.871,06	R$ 7.337.871,06
(-) Investiments	R$ 17.662.272,08	R$ 7.214.167,47	R$ -	R$ -	R$ -
(=) NET CASH FLOW	**-R$ 16.613.832,12**	**-R$ 1.563.106,39**	**R$ 7.337.871,06**	**R$ 7.337.871,06**	**R$ 7.337.871,06**

1.7.2.5.1. VALUE FOR MONEY

Finally, the value for money analyses took into consideration the transition strategy, where the costs of the current billing system were proportionally inserted. Thus, it considers that those employees involved in ticketing activities are reallocated in other operational activities where there is a need for hiring.

Therefore, the tables below show the total cost of the billing activity for the next 5 years from two perspectives:

a) Considering the proposed new system

Table 29 - Value for money / Strategy 1 - METRÔ-SP SP

	Year 1	Year 2	Year 3	Year 4	Year 5
Costs of current system	73.378.203,11	41.846.116,42	28.267.434,05	28.267.434,05	28.267.434,05
Costs of new system	R$ 3.322.975,20	R$ 20.948.424,01	R$ 26.563.408,57	R$ 26.563.408,57	R$ 26.563.408,57
Total Costs	R$ 76.701.178,31	R$ 62.794.540,44	R$ 54.830.842,63	R$ 54.830.842,63	R$ 54.830.842,63
Total accumulated	**R$ 76.701.178,31**	**R$ 139.495.718,75**	**R$ 194.326.561,38**	**R$ 249.157.404,00**	**R$ 303.988.246,63**

b) Keeping the current system

Table 30 - - Value for money / Strategy 2 - METRÔ-SP SP

	Year 1	Year 2	Year 3	Year 4	Year 5
Costs of current system	80.764.097,29	80.764.097,29	80.764.097,29	80.764.097,29	80.764.097,29
Total accumulated	**R$ 80.764.097,29**	**R$ 161.528.194,58**	**R$ 242.292.291,86**	**R$ 323.056.389,15**	**R$ 403.820.486,44**

Figures shows that over the next 5 years the ticketing system through QRCODE will represent a saving of R$ 99.832.239,81 for METRÔ-SP SP.

1.8. CONCLUSION

Considering the presented data in this project, one may consider several conclusions about it.

The first is that the current technology used in Edmonson type is no longer compatible with modern day necessities, especially on an age of enormous data usage. To consider a non-traceable, easy to forge, limited applications ticket is one of the most inefficient methods of ticketing. On top of that, the huge costs for Operations (Manufacturing, Value transportation, Manual handling at stations) and Maintenance (Trained workers and spare parts inventoried to keep stations blockades´ lines avail) doesn´t appeal as a profitable business model, if you consider ticketing as a niche.

The second conclusion, is that it is a viable solution when considering execution feasibility if considered companies figures where shows that over the next 5 years the ticketing system through QR Codes will represent a saving of R$ 148.871.827,46 for both CPTM and METRÔ-SP combined.

The third, and most important, conclusion is that comparing several technologies, QR Code presented the best balanced solution: Increased operational efficiency and decreased costs. On top of that, passenger perception changed, where 94% reported that the time they took to buy tickets decreased, comparing to the formerly applied solution with Edmonson and 88% considered the overall process better, or at least the same, when compared to Edmonson type tickets. Additionally, several passengers reported that the use of QR Codes made the impression of a more modern ticketing system, which technically is irrelevant since the only real change applied was the replacement of Edmonson.

That being said, we may position ourselves on two situations: (i.) as those who use the railway system: the application of this new technology may bring passengers´ experience to a new level of trust and image gains; (ii.) and as those managing the company: state-of-the-art operational efficiency applied as it best.

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APPENDIX

Appendix A: Risks List – 5 pages;

Appendix B: Standard SWOT analysis – 1 page;

Appendix C: Cross-SWOT analysis – 1 page;