A New Innovative Model Using RFID: A System Design and Its Implementation

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Abstract – **In this study an innovative RFID model is presented. This is a very innovative concept, pursuing a new way of looking at current systems as well as their potential. This model includes the necessary equipment, includes also the current systems and the different business areas in which the company operates. The aim of this study is to bring together the existing processes and technologies, providing a different solution, organizing a different way of operating and offering a more efficient approach. The aim is also, by offering certain products and services, to become part of a project embraced by a company, with an interest in developing it given that it has the capacity for its implementation. In this particular case an essay of the network model was presented to Brisa Inovação e Tecnologia, MARL - Mercado Abastecedor da Região de Lisboa and Frigoservice. This model can be applied to individuals or to the services they may need, such as the anticipation of compact traffic on a lane, thanks to the real-time information of passage speeds in certain frames. Is also shown in this study the equipment that permits the model that is presented to become possible (the OBUi equipment).**

Keywords - *Networks, interoperability, processes, technology, RFID, OBUi*

1.   Introduction

This work was developed from the idea of trying to find union points between a set of existing technologies, already implemented and in current use by the Portuguese company Brisa Auto Estradas de Portugal, SA for toll collection (as the Via Verde Portuguese Electronic Toll Collection system), and a set of processes nowadays more and more used by Logistics.

The activity of the company Brisa Inovação aims to ensure the skills and activities related to research, design, development, production, installation, support and maintenance of all the equipments, systems and intelligent transportation services that support the operation and exploitation of motorways. For this new project, the company intended to compile the necessary elements to enable the design of a new innovative RFID model, which main objective would be to determine which services are actually required by the logistic operators, and how to link them to the technologies used by the company for its actual core business of Electronic Toll Collection (ETC) based on 5.8GHz DSRC (Dedicated Short Range Communication) technology.

Presently there is a new scenario in Portugal concerning toll collection. There is the disappearance of roads previously without direct cost for the user (and without toll) called SCUT, and now there is also the appearance of a new equipment to be installed on board vehicles for toll payment purposes called DE (electronic device), commonly known as OBU (On Board Unit). Consequently there is now a new competitor in this area. Brisa has no longer the monopoly of this kind of technology in the market in Portugal.

Moreover, at the wider level of the European region there are also important changes, as a reflex of the White Paper of Goteborg signed in 2001 (COM, 2001), and mostly because of the European Commission's Directive known as Eurovignette (Viegas, 2005; Borgnolo and Rothengatter 2005; Nash and Matthews, 2005). This new environment came to accelerate the implementation of several changes, which will largely affect all the motorway concessionaires in the UE, and also their toll collection systems.

The White Paper concerning Transport European Politics (COM, 2001) contains clear objectives on security and road traffic flow which, in conjunction with the growing mobility of people and goods using roads in the European Union space, makes essential

to safeguard the transport infrastructure's quality, as well as the effectiveness of the means used. This warranty is increasingly dependent on the use of toll schemes and the progressive generalization of electronic systems for its collection.

The Portuguese Law number 60/2008, published in September 16th 2008, authorizes the Government to legislate on the mandatory installation of a license plate electronic device in all vehicles authorized to circulate on the high-ways or similar roads.

Therefore, there is a business opportunity for the companies that possess more know-how and means in respect to these toll systems, as it is the case of Brisa. Anyway, considering precisely these systems (i.e. identification and electronic tolls), it can be said that they are mandatory, either in terms of recent Portuguese laws (DL n. ° 111/2011 and 112/2009, Portarias n. ° 314-B/2010 e 1033-C/2010) or in terms of the Eurovignette Directive in UE (European Parliament and Council of the UE, 2006). These systems are exactly the ones used by the company Via Verde (held by the Brisa holding), which has the control of these systems in Portugal, covering all the existing motorway concessionaires (and not just the concessionaire Brisa, the company which owns Via Verde).

The main objective of this work is to obtain a new set of processes and collaborative networks through the existing technologies that by themselves can not evolve in the same way. To achieve this central objective, a new model is built.

The mentioned model is an innovative model that can be applied to any company that already uses RFID technology. It allows, with a minimal investment, to take advantage of this technology and to let companies become more competitive. On this particular case, considering this project, the model was presented to the companies Brisa Inovação e Tecnologia, MARL – Mercado Abastecedor da Região de Lisboa and Frigoservice. All the involved companies play an important role either in the installation or in the advice on the use of leading technologies. Moreover this role is important where interoperability is a strategic advantage for all the entities involved.

After this introduction, a review follows of relevant literature about collaborative networks, interoperability and decision analysis. Afterwards, the methodology used will be explained and finally,

just before the final notes, the new innovative RFID model will be presented.

2.   Literature Review

2.1. Collaborative Networks and Interoperability

Over the last decades there was a huge technological evolution at all levels, but a big concern exists now: the problem with interoperability. Nowadays we have a gap between processes and technologies (figure 1).

Simultaneously - and trying to make the connection between them - countless systems of Organizations Systems Information (OSI) were born and are trying to subsist. Due to the high pace of technological changes and process needs they subsist (but for short periods), and in the end they are like "small islands" in this immense "ocean" that is the referred gap (figure 1).

Figure 1. Gap between processes and technologies

These information systems are also known as subsystems (automation islands).

According to Osório et al. (2010), collaborative networks are essential for the modern and future design in order that technological platforms could be supported by the leverage of numerous disconnected processes and because of a more and more disordered and not integrated technological growth evolution that often gets eventually lost. And consequently so is the platform that could have assimilated it.

Interoperability is the ability of two or more systems or components to exchange information and to use the shared information without having to make any considerable effort on any one of the systems.

While the business activities are those that create value in the business process, the interoperation activities are non-added value activities. They represent the efforts of interoperability in the information exchange among the different partners.

Despite this, recent studies (Osório et al., 2010; Camara et al., 2010; Ertico ITS, 2008) show that it is possible not only to apply a methodology for the

analysis of interoperability, but also that interoperability can be represented and measured.

Camara *et al.,* 2010 developed an evaluation framework, which permits to quantify interoperability, providing an estimation of the improvement in the performance of a particular process and permitting to understand the benefits to be expected in consequence of the achievement of objectives. The study proposes a framework and methodology for assessing the impact of interoperability in a supply chain. The result is an excellent contribution to the defense and affirmation of the collaborative network, showing that the use of business process models can serve not only to situate the activities of inter-operation and interoperability barriers, but also to measure their own interoperability (figure 2).
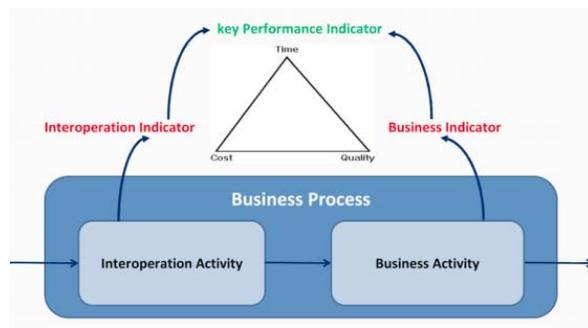

Figure 2. Interoperability representation and measurement (Camara *et al*., 2010)

According to Capó-Vicedo et al. (2011), Askarany et al. (2010), Bayraktar et al. (2008) and Bonfill et al. (2008) an effective Supply Chain Management (SCM) implies:

• Efficient integration of suppliers, manufacturers, warehouses, and stores.

• To reduce cost, increase service level, reduce the bullwhip effect, make better use of resources, and effectively respond to changes in the market place (Sucky, 2009; Bayraktar *et al*., 2008).

It is critical to implement effective distribution strategies, regardless of the total level of supply chain integration (Parment, 2008; Chopra, 2003).

There are two main Distribution Strategies:

• Direct Shipment: items can be directly shipped from the supplier or manufacturer to the retail stores or end customer

• Intermediate Inventory: it uses intermediate inventory storage points, Warehouses or Distribution Centers (DC)

In accordance with Alpan et al. (2011), Tang and Yan (2010) and Egbelu and Yu (2008) Cross Docking (CD) avoids inventory and maintenance costs, and was initially popularized by Wal-Mart. CD choice implies a significant start-up investment and is very difficult to manage (Ma *et al.,* 2011). For that reason, Supply Chain partners must be linked with advanced information systems for coordination, and a fast and responsive transportation system is necessary (Arabani et al., 2011; Boysen and Fliedner, 2010; Vis and Roodbergen, 2008), in order to achieve that:

Warehouses function as inventory coordination points rather than as inventory storage points

• Goods arriving at warehouses from the manufacturer:

  o are transferred to vehicles serving the retailers

  o are delivered to the retailers as rapidly as possible

• Goods spend very little time in storage at the warehouse:

  o Often less than 12 hours

  o Limits inventory costs and decreases lead times

This allows them to ship goods from warehouses to stores in less than 48 hours and to replenish stores twice a week on average. In figure 3 we can see the main scheme of a Cross Docking (CD) system, and also the difference when the CD does not exist.
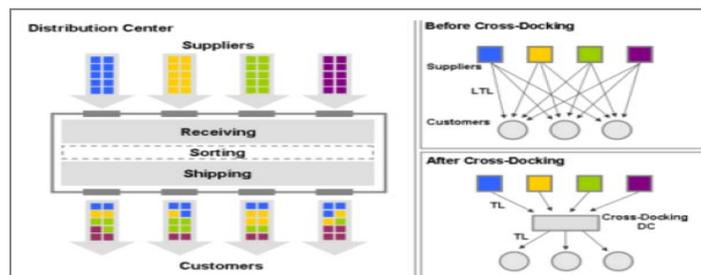

Figure 3. Cross-Docking Scheme (courtesy of Relvas, S., 2010, DEG - IST)

According to Ubeda *et al.* (2011) and Xuezhong *et al.* (2011), here are some flash images on Green Logistics, concerning the subject of this project:

• 25% of trucks km in EU countries run empty, rising up to 37% in Ireland (Eurostat, 2007)

• In the UK food supply chain, only about 52% of the available space in laden trips (trips with load) is actually occupied by a load

• Horizontal Integration ==> Backhauling ==> Can achieve 20-40% savings in transportation costs

The evolution of Intermodal Combinations (Ishfaq and Sox, 2010; Macharis *et al.,* 2010; Ricci and Black, 2005), in particular the case of Piggyback (TOFC/COFC), and also third parties (Jayaram and Tan, 2010;Carbone and Stone, 2005; Ying and Dayong, 2005), will be surely relevant in the medium and long term basis:

• Intermodal Marketing Companies act like shippers' associations or cooperatives

• Third-party Logistics Service Providers:

  o   Sector with high growth ratio in the EU

  o   Advantages: management of information by the 3PL, freeing the company from day-to-day contact with carriers

  o   Main activities are freight payment and dedicated contract carriage

3.   Methodology

3.1 DSRC and CN/GNSS Technologies

This study will be confined to the recovery technologies that fit into the context of use on vehicles, particularly in the collection of tolls in motorways and roads, on accessing venues that require payment of fees (e.g. parking lots), and of all / any service forming a working scheme requiring identification or requiring that vehicles pay for its use, as in the case of purchasing products at a petrol station or convenience store, for instance.

The first step in identifying technologies for charging is to determine the functional requirements, and the second is to translate them into technological options.

There are three main approaches for charging, each comprising a cluster of the technology, considering the following building blocks: DSRC, CN/GNSS and ANPR. DSRC and GPS have evolved in parallel from very different origins, and both were conceived as tangible technology in the mid 1970's. Both went through several generations, both are available in mass-market products, and both are well supported

by an internationally competitive industry. But they perform completely different functions (communications and positioning, respectively).

The importance of usage is directly related to the business case. To use the highest is "better", with greater degrees of automation in order to capture the benefits of economies of scale and a reduction in transaction costs (figure 4).
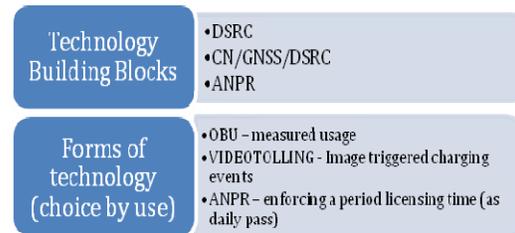

Figure 4. Technologies (availability and/or need)

A scheme designer, making decisions on charging technology choices, will also need to consider the degree of automation, influenced by several factors, including the numbers of charging events, vehicles and accounts, as can be seen in figure 5.
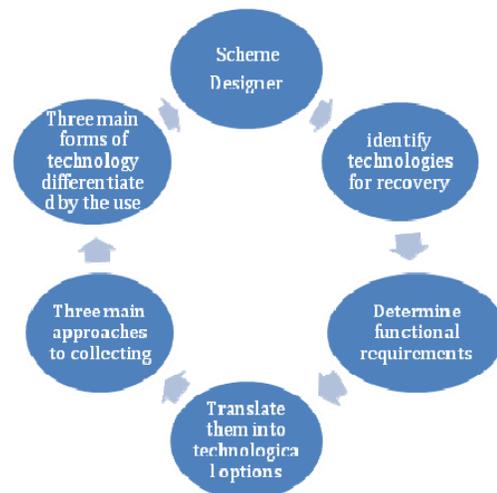

Figure 5. Relationship of functional requirements identification and choice of technology

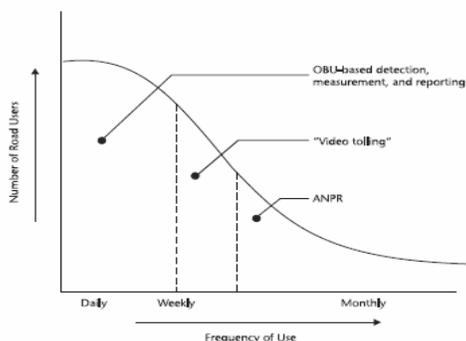Figure 6 shows the relationship between three technology forms, differentiated by usage:

Figure 6. Technology choice and usage (Persad *et al.,* 2007)

3.2 MCDA – Multicriteria Decision Analysis

In accordance with Sanchez and Bana, (2009), Bana Consulting (2005) and Lourenço (2002), there are several kind of decision analysis multicriteria models, that can be split in two large groups: the compensatory and the non compensatory.

From all these models, because of being probably the most widely used of all multicriteria models, stands out a compensatory model: the simple aggregation additive model.

For this work is considered the hierarchic additive model in order to obtain some of its parameters – criteria weight coefficients – that would help us in the decisions on choosing what services are best fit to purpose.

The MCDA recommended methodology (Sanchez and Bana, 2009) was followed, with the following steps:

1. Decision context analysis and decision support process organization

2. Organization of evaluation elements

3. Development of evaluation multicriteria model

4. Sensitivity and robustness analysis, and preparation of recommendations

4.   Technological Development

4.1   DSRC – Dedicated Short Range Communications

According to Jaber *at al.* (2011), Rezaei *at al.* (2010), Coronado *et al.* (2009) and Kim and Kang (2004) DSRC is a localized, bidirectional, high-data-rate channel that is established between a fixed roadside system and a mobile device installed inside a vehicle. The most widely used frequency bands for DSRC are

902 to 928 MHz (mainly in North America); 5.8 GHz (mainly in Europe, South America and Southeast Asia) or 5.9 GHz, depending on locally applicable standards; plus infrared frequencies (mainly in Southeast Asia).

The most common applications of DSRC are ETC at toll plazas Lee *el al.* (2008) and localized communications for enforcement as part of GNSS solutions (e.g. German truck tolling scheme), Doll and Link (2007).

4.2   CN/GNSS – Cellular Networks/Global Navigation Satellite System

As Fernández (2010), Urschl *et al.* (2007) and Dow *et al.* (2007) presented in their papers, GNSS technology within an OBU estimates position by combining measurements of signals from a constellation of orbiting satellites, typically GPS or GLONASS. CN refers to the bidirectional communication between an OBU and a fixed network of terrestrial transmitters, usually commercial cellular devices (figure 7). The positioning function needs to be specified, and the reporting strategy also needs to consider that cellular network coverage is not always possible. Alternative methods of reporting may need to be considered.
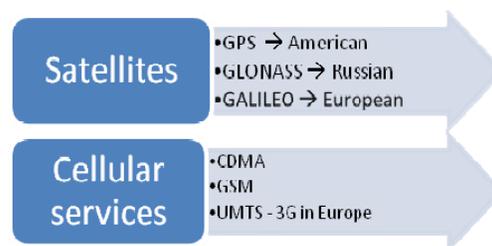

Figure 7. Satellites (GNSS) and Cellular Networks (CN) in a CN/GNSS system

4.3 ANPR – Automatic Number Plate Recognition

The dataset used in our empirical analysis consists of seven daily stock price series representing the G7 countries: US, Canada, Japan, UK, Germany, According to De Palma and Lindsey (2011) the ANPR - Automatic Number Plate Recognition, is the only one of three technologies mentioned in the building blocks that do not need any equipment or device installed inside or outside the vehicle. For this reason, it is most suitable for occasional users.

In its evolution, this technology, which took the first steps in the eighties, has undergone several changes in its type of use. In the 80's of the twentieth century

it was used to control access for closed user groups. In the 90's, it was used as support to enforcement procedures of manually paid parking. And since entering this millennium, its use has been wider, both with ANPR cameras to match vehicles with their OBUS and to be used in the enforcement of urban charging schemes (e.g. London Congestion Charging).

4.4 A New Innovative RFID Model: System Design and Implementation

An innovative RFID model is presented in this work. It allows seeing the mode of operation of the actual RFID models applied to Logistics, with new assumptions. Instead of using RFID tags in all products, then in boxes, and in pallets, and also in containers…and to have a set of expensive readers spread at all steps we need to take, first inside factories, then in supply chain warehouses, followed by the loading docks, and again, until the final installations: hypermarkets and stores, all of this makes this process too complex and too expensive.

Instead of all of the above mentioned, the new model proposes to take advantage of a net supported on the DSRC system, already implemented and until now being used for other purposes, at "no cost".

Therefore, with only some arrangements in the equipment's On-Board Unit (OBU) that will be installed inside the vehicles and in system interfaces, we can implement an RFID Model applied to logistics in a much simpler way, while being a much less expensive one.

For this purpose, a research on the market of this kind of equipment has been done. It was found that the required OBU already exists. It is a patented on-board unit, resulting from research and development made by a Portuguese company, in partnership with three Portuguese Universities and also the Brisa Inovação Company.

It is called OBUi, and integrates both DSRC and CN/GNSS technologies (Figure 8). The "i" means interoperability, which was precisely what was intended with this model. In this case, the interoperability is between the two electronic toll collection (ETC) systems most used currently, and therefore it was thought out to function also with the CN/GNSS system. For that reason, this OBUi equipment has an incorporated GPS device, and also a GSM/GPRS Cellular Network access chip for establishing mobile communications. The DSRC is

MDR (Medium Data Rate), therefore it has both the desired capacity and SIEV´s certification requirement fulfilled. And obviously, it is prepared for being used in all of the UE countries (most countries function in MDR, and as Via Verde was a first mover in this technology, until last year only functioned in LDR mode - low data rate, and it was not possible to operate outside Portugal, neither to accept foreign OBU-MDR). Nowadays, the migration from LDR to MDR was completed (2011) in all RSE (road side equipment), and all OBUs sold nowadays are MDR.

Figure 8. Picture of the OBUi (courtesy of Osório *et al.,* 2010 (GIATSI-ISEL)

A provider is identified in Portuguese regulations as a toll collection issuer or provider. The provider is responsible for supplying the OBUs to the market (directly or through distribution agents authorized by SIEV, SA). Via Verde Portugal is already a provider under the DE framework authorized by SIEV (figure 9), therefore when Brisa Inovação will be able to certify the new OBUi, the new equipment will be operative for the new services and activities of Via Verde, as a provider of the private Via Verde OBUi DSRC-MDR scheme (but now also with an incorporated GSM/GPRS permitting to work in a CN/GNSS scheme).
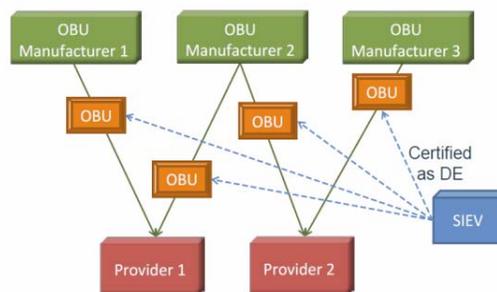

Figure 9. Suppliers and Providers of OBUs (SIEV-Sistema de Identificação Electrónica de Veículos, S.A, 2010)

The two applications adopted by SIEV, SA for the implementation of DE system are Automatic Vehicle Identification (AVI) and Electronic Fee Collection (EFC).

The DE AVI application for Portugal is based on three attributes: Manufacturer ID, CS1 Issuer Serial Number and Private1 (vehicle toll class), from the unique associated element. The DE AVI application consists on a subset of the already defined attributes and a set of private ones. This application will be exclusively accessed by authorities (police and other authorized entities) under security, level 1, as it guarantees authentication of both OBU and RSE. This application is for future use only, so that presently adopted OBUs are able to comply with eventual future requirements, namely if decided at European level (figure 10).

The EFC application is currently used for tolling, parking and gas station payment, and can therefore be used for other electronic collection services, in line with the current uses of Via Verde OBU DSRC-LDR services already offered.
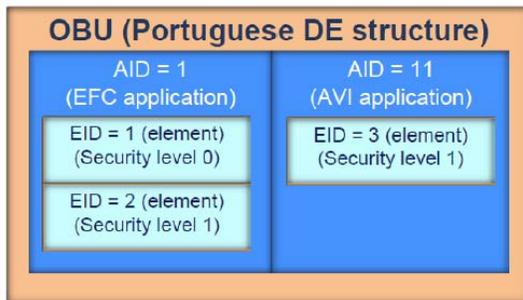

Figure 10. DE information structure example (CEN-Technical Board resolutions, 2007)

According to the ISO-14906 DSRC standard, OBU's information structure is organized in applications with an associated unique identification (AID). Each application must have at least one element with an associated unique identifier (EID). Each element is organized in a number of attributes, each one complying to specific application requirements. The OBUi structure should also include a system application with a single system element, with specific attributes that are of manufacturer's responsibility (figure 11).
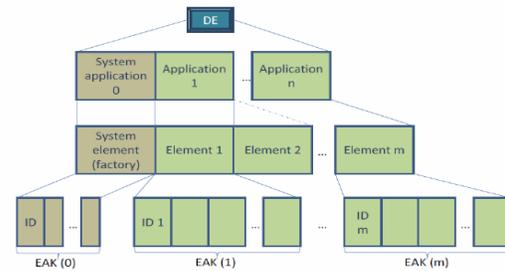

Figure 11. DE information structure (SIEV SIEV-Sistema de Identificação Electrónica de Veículos, S.A., 2010)

For the personalization process, each element is secured through an EAK (Element Access Key) or a similar security method. This is a critical point in the Model building, because it is in this certification that lies the key success factor of the whole model: the opportunity for certifying new applications which ensure the new functionalities of the new OBU, that will itself also be certified.

In figure 12, the complete scenario scheme of the Innovative RFID Model operation can be observed, which serves as the basis for the Brisa Inovação project, the subject of the present case study.
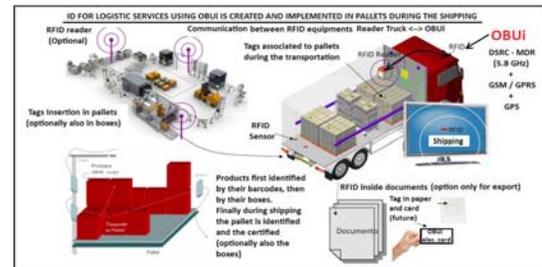

Figure 12. Complete scenario scheme of the Innovative RFID Model operation

4.4.1 Scenarios for Automated or Semi Automated Inspections

In the case of operations by the Stop Tax Brigades, the layout of the scenario will be the semi-automated surveillance. This control can be done using handheld terminals for a mixed reading system (bar code and RFID), for the case of roving surveillance that takes into account site visits (reading terminals, more portable players) as can be seen at the left of figure 13.
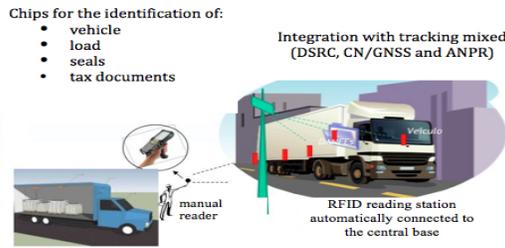
Figure 13. Scenarios for automated or semi automated inspections (stop police operations)

In the case of fixed police control points, such as in certain country border areas which are crossed by passing output freight for Europe, or in the access of very large ports with higher flow of containers, or even at strategic points in the access of logistics parks or industrial cluster areas, a setting scheme of automated inspection may be chosen, as can be seen in the right part of figure 13, and in more detail in figure 14.
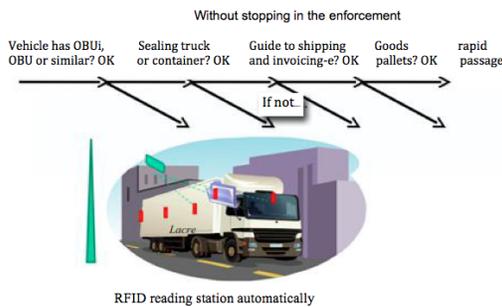

Figure 14. Scenario for automatic inspection ports and control lanes (future application)

4.5 Decision Analysis

For a better use of Multicriteria Decision Analysis (MCDA), it became very useful to rely on the MACBETH Method (Bana et al., 2011; Sanchez-Lopez and Bana, 2009; Berrah and Clivillé, 2007), that was used resorting to the M-MACBETH Software (Bana Consulting, 2005) which is the Decision Support system that implements by computer the MACBETH Method. The evaluation multicriteria model was directly developed, using the M-Macbeth software, with four decision criteria:

1. The attractiveness that new services could have in future for the actual clients;

2. The attractiveness of those same new services for new possible clients;

3. How much can these new services affect (positively) the global company volume of turnover at the medium-term;

4. How much can these new services help to increase the total margin of the company (either by costs reduction or sales of high margin services – higher value added).

A judgments' matrix was made taking into account the weights, now included among the four criteria from each other. It was then obtained the representation of the Weight' s Matrix Macbeth scale (figure 15).
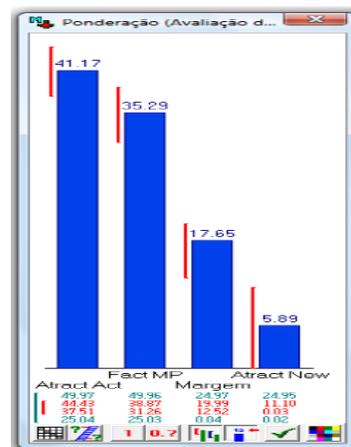

Figure 15. Weight's Matrix Macbeth scale

Finally, it was possible to obtain the Scores Table (figure 16a), This table can also be transformed in a graphic scale, called Global Thermometer (figure 16b)
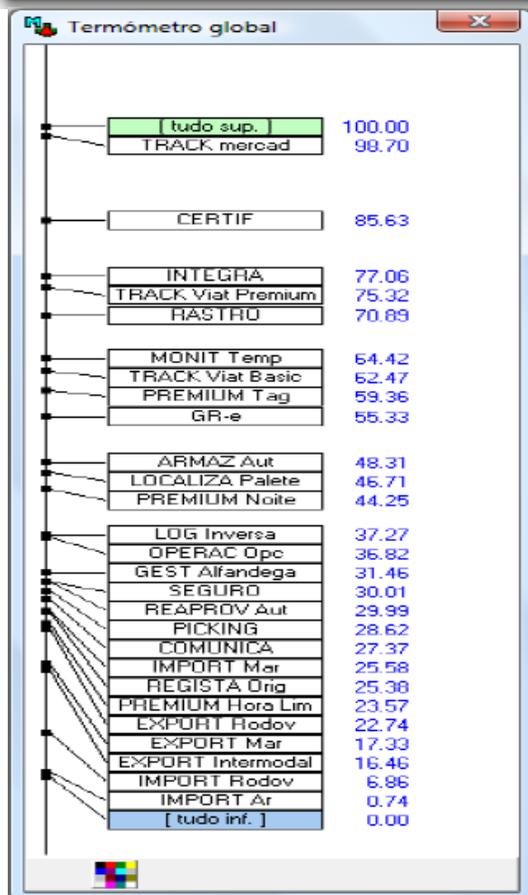

Figure 16 a) Table of final Scores and **b)** Global Thermometer Scale

It is evident that there are two sets of services, from the 27 previously selected, a first set with 12 services, which punctuation (preference) overpasses 44%, and another set, consisting of 15 services, which punctuation is lower than 37%, from which 2 services, can be excluded from the start (IMPORTar and IMPORTrodov).

Finally, we can understand by the selected services set (first one with 12 services), and by the actual interview itself with our decision-maker, that the preferred strategy by the company Frigoservice (MARL´s warehouse with Cross Docking), is Strategy B, which "heavy" weights are those we can see in a simple way in figure 17.

Figure 17 – Choice strategy balance

5.   Technical Challenges

From assessment of needs, with regard to equipment and technologies for the implementation of the proposed model, we detected several types of equipment not now found in the Portuguese market, at least in a direct manner, and this will be one of the technical challenges to explore:

• Seals (mechanical, printed seals with a chip) to lock loads, pallets & packaging, and authentication of documents (future application for export);

• Chips shipped placed in pallets, specially designed for this purpose;

• Security electronic seal (890-920MHz) device, with engine encryption and security keys for recording, and operation seals and other special-purpose versions (can only be designed and manufactured in Portugal), future application mixed with WAVE (Wireless access for vehicular environment) Xiang et al. (2008)

• Approval and certification of equipment.

As for equipment on the market, it is important to note some of the technical specifications, so they can function in both CN / GNSS, such as DSRC, which are considered most relevant:

• Readers / Writers (890-920MHz, 4.8-5.9GHz);

• OBUs should have minimum storage capacity of 1024 bits;

• OBUs must permit their attachment into the vehicle so that they become physically inoperative when removed from the original location;

• OBUs must have recording features that prevent data change.

It is crucial to get the clearance of restrictions on certain equipment and technologies and to evaluate the stability of tags (temperature, washing, etc.), because for example in the case of freezing, they must withstand temperatures in the range of negative 22 degrees Celsius, and often water and ice.

And as a final note it is important to say that the Back-Office is a critical part of the model. This support structure should consist of an architecture independent server system, and should secure the integration of the data for identification, tracking and authenticity of goods, which must be connected to the core infrastructure in major firms, as well as to key customers.

6. Summary

Regarding the integration of key elements of the model (essentially OBUi equipment, short range RFID readers and systems gantry with DSRC), a survey was made of a series of interfaces that should be needed:

• Interface for mobile devices (mobile phones and similar), for Brisa and system users, stratified by controlled access;

• Interface for migration of data between two systems present in vehicles;

• Web interface for managing the logistics of interest to users;

• Web interface for the automation of taxation within the participating companies, to interface with other related systems, such as electronic billing and other services that may be available;

• Web interface for the Departments and the Ministry of Finance, as well as, if possible, for the system that

manages Citizen Shops, with the information and automation of these departments, automatically correlating with other systems of relevance to the tax agencies, with versions for tax brigades and portable devices.

Therefore, and finally, it will also need a system capable of integrating the referred software interfaces.

In the perspective view of future users of the OBUi and their engaged services, the following expected gains for the clients should be noted:

• Administrative costs reduction

• More efficient cost control

• Reduction/Change of fixed costs in relation to variable costs

• More efficient Cross-docking

• Better management of incidences / complaints

• Differentiation

• Brand / company image

• Less bureaucracy

• Better performance of logistic processes

• Reduction of goods thefts in all the Supply Chain Management (SCM)

• Better vehicle flow control in distribution centers (DC) and Logistic Parks

• Concordance in flow and tracking of goods: Goods / Documents / Hauler

• Increased transportation and information Safety

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