# RFID TECHNOLOGY IN A CONTAINER PORT: AN ACTIVITY-BASED MODEL TO ASSESS COSTS AND BENEFITS

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## Abstract

The use of Radio Frequency Identification (RFId) in a container terminal can lead to great benefits, improving the efficiency of both the identification and the handling activities, thanks to the better use of the equipment (e.g. cranes, vehicles). Moreover, it allows a better tracking and tracing of the containers both at the terminal and the supply chain level. Despite the interest in RFId applications and their great potential, literature still lacks models to assess the RFId impacts on a container port activities. This paper aims at filling this lack by presenting an activity-based model to evaluate the costs and benefits that stem from the adoption of RFId in a container port. The model takes into account a general container terminal which manages different kinds of containers (e.g. standard, reefer, etc.) and it considers all the activities from the container arrival to the shipping, including different actors. The economic impact of RFId adoption is quantified, and several useful information regarding feasible adoption scenarios are provided.

## Keywords

RFId, model, benefits, container terminal, port.

## Introduction

Container ports are becoming increasingly important: between 1996 and 2003 the entering flow of goods in the Italian commercial ports increased of the 27.5%, whereas the number of entering containers increased of the 134% (Confindustria, 2006). To manage efficiently and effectively the incoming and outgoing containers is becoming a strategic factor for container terminals. Radio Frequency Identification (RFId) technology has a great potential in a container port environment by improving the container traceability and increasing the efficiency of the handling activities. Several ports are starting to evaluate or use this technology: for instance, the Busan port in South Corea took into consideration the possibility of using RFId to reach a better efficiency and security in shipments, whereas Los Angeles and Hong Kong ports focused on the possibility of automatically identifying container violations.
Despite all the interest in RFId applications, literature still lacks models to assess the impacts of RFId technology on the container port activities. This paper aims at dealing with this point, analysing the activities which are expected to be affected by the technology: a general framework to evaluate the costs and the benefits related to the introduction of RFId in a container terminal is provided, together with an economic evaluation applied to a large Italian container port, acting as a test case.

## The model

### The reference processes

The model takes into account a general container port which manages different kinds of containers (e.g. standard, reefer, etc.), with two different actors operating in the port environment: the terminal operator and the Customs authority. It considers all the activities from the container arrival to the port up to the shipping.
More in detail, the analysis carried out for the terminal operator considers the relevant processes for containers entering by sea (import) or by land (export), namely:

- the activities in the container port carried out by the terminal operator (reservation, access control, container movement inside and outside the yard, internal movements, loading and unloading, complementary activities);
- the information and the document flows;
- the people involved in the activities.

As for the second part of the model, all the activities carried out by the Customs authority have been analysed, namely:

- controls on the entering goods – import ("entry visa");
- management of the *groupage* goods;
- controls to let the container exit the port ("exit visa").

In both cases, every activity has been analysed at the elementary level in order to understand the micro-activities on which RFId technology mainly impacts. As for the terminal operator, the analysis showed that the activities more influenced by the technology are the access control and the yard management. As an example, Figure 1 shows the activities modelled for the access control carried out by the terminal operator, focusing on entry controls only.

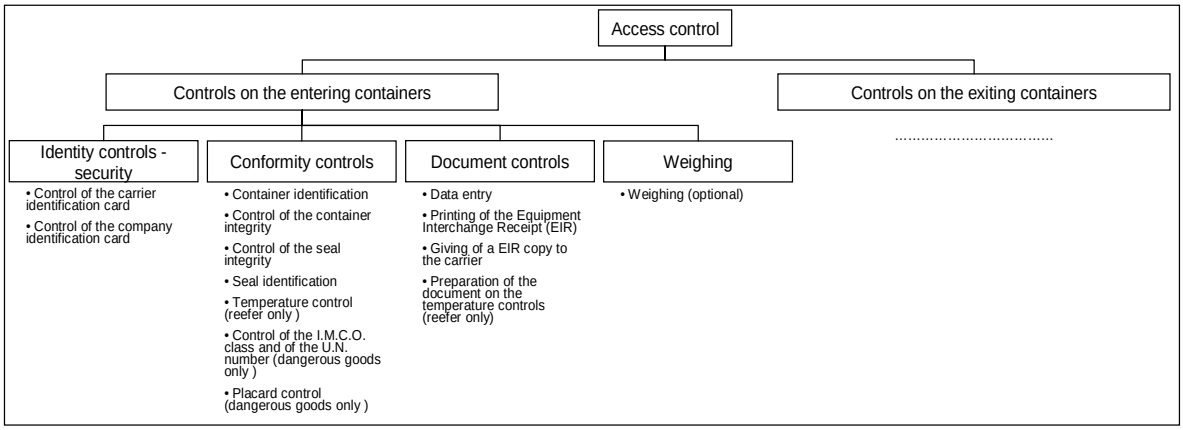


Figure 1: Access control activity by terminal operator

**The technological scenarios**

The model takes into account several RFId scenarios, which differ in:

- the tagging alternatives: either the container has to be tagged when entering the container port (option 1) - therefore both the cost of tag and the cost of tagging are incurred by the terminal operator - or the container is already tagged when entering the port and a service fee might be required to access the container identification data (option 2);
- the identification alternatives: either active tags that record only the container identification number or electronic seals, which provide not only the container identification data but some additional information (e.g. to certify the container integrity).

For the sake of convenience, only a subset of all available combinations will be discussed in this paper (cf. Table 1).

| RFId SCENARIO | CONSIDERED ACTOR | TAGGING ALTERNATIVE | IDENTIFICATION ALTERNATIVE | CONTAINER FLOWS |
|---|---|---|---|---|
| A | Logistic operator | 2 – the container is already tagged | 1 – Active tags | Import & export |
| B | Logistic operator | 2 – the container is already tagged | 2 – Electronic seals | Import & export |
| C | Customs authority | 1 – the container has to be tagged | 2 – Electronic seals | Only import |
| D | Customs authority | 2 – the container is already tagged | 2 – Electronic seals | Only import |

Table 1: The considered RFId scenarios

The choice of considering only the alternative in which the container is already tagged in Scenario A and B is due to the fact that one of the activities that the logistic operator would like to quicken and

improve is the access control, and this is possible only if the logistic operator does not have to tag the entering containers. Both tagging alternatives are instead considered for the Customs authority, since here the focus is more on the possibility of quickly find the container to be checked within the yard more than on improving the access control. Moreover, whereas both the identification alternatives are considered for the logistic operator, only the electronic seal solution has been assessed for the Customs authority, since it is more interested in a solution able to guarantee higher security.

As for the RFId infrastructure, every gate and every spreader has to be provided with RFId readers and antennas in order to identify the containers (cf. Figure 2).

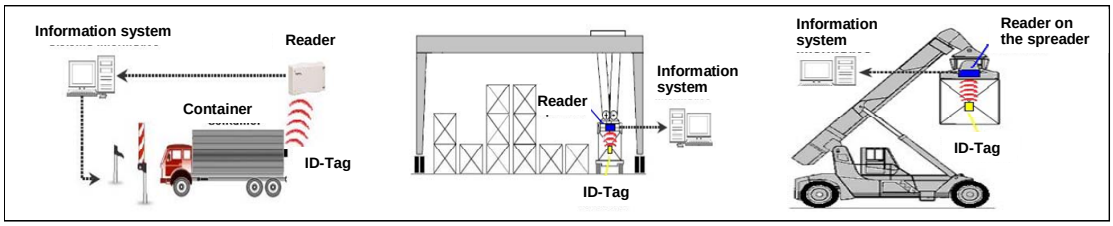


Figure 2: The RFId infrastructure

In order to assess the costs and the benefits, a base-line scenario (considering the typical activities now carried out in a container port) has also been considered; this base-line scenario is characterised by a manual identification of the container unique code and a manual control of the mechanical seal.

**The structure of the analysis**

The assessment model is made up of three components, strictly related:

- the assessment of the operational benefits;
- the assessment of the recurrent costs and the investments;
- the assessment of the non-operative benefits.

The assessment of the operational benefits focuses only on the differential activities impacted by the RFId technology adoption (cf. the reference processes); for instance, for the terminal operator, only the access control and the yard management have been considered.
Every activity has been analysed in depth with an Activity Based Costing approach for each technological scenario in order to reach the required level of accuracy and to understand how and where the process changes with the adoption of RFId (both in terms of time and costs).
As for the investments, for each technological scenario an analysis of the RFId infrastructure and of the implementation costs have been carried out in order to assess both the investments and the recurrent costs (e.g. tag substitution, system maintenance, etc.).
As for the non-operational benefits, the model analyses the most relevant impacts of the RFId application in terms of service (e.g. reduced time spent in queue or at the gate), environmental benefits and other intangible benefits (e.g. improved visibility).

**The results**

In this paragraph the results obtained from the application of the assessment model are presented: a large Italian container port in Northern Italy was involved both in the model design and validation and in the RFId assessment phase.

**The operational benefits**

To evaluate the operational benefits in the selected technological scenarios, four clusters of parameters have been considered:

- the costs of labour and equipments (e.g. workers, fuel used in transtainers);
- the container flows (e.g. flows of full containers - Export);
- some infrastructural data (e.g. number of loading/unloading docks, number of transtainers, number of front loaders, % of containers moved by transtainers);
- the duration of the key elementary activities (e.g. time spent for the driver identity control, etc).

Several of the presented parameters are related with the container flows: i.e. the largest commercial ports are located in the far-east, where the labour costs is low and the equipments are cheaper than elsewhere.

The model has then been applied to a container port with a yearly flow of about 190,000 TEU (Twenty-feet Equivalent Unit).
The overall operative benefits that can be achieved by the terminal operator under the assumption that the containers have already been tagged when they enter the port (integrated supply chain – scenarios A and B) are summarised in Figure 3.

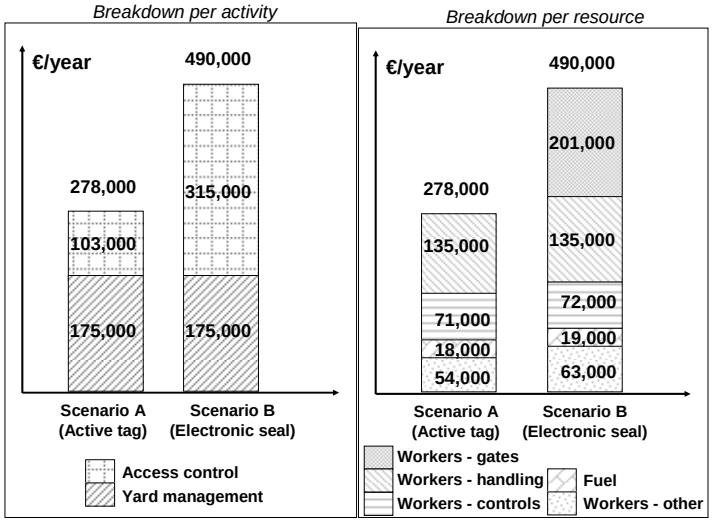

Figure 3: The operational benefits – Scenarios A,B

The operational benefits that can be achieved with the electronic seal (scenario B) are near twice as much as with active tags (scenario A), due to the possibility of automatically identifying not only the container but also the seal. The overall operational benefits are about 278,000 € (1.45 €/TEU) when active tags are used and raise to 490,000 € (2.55 €/TEU) when the containers have been provided with electronic seals. Basically, the two RFId scenarios (A,B) allow to achieve the same benefits in the yard management (with a flow of about 190,000 TEU, benefits are close to 0.90 €/TEU), while scenario B (electronic seal) allows to reach much higher benefits in the access control activity (more than 300,000 € per year, which are three times the benefits that can be gained with the active tags). As shown in Figure 3 - breakdown per resource - 40% of the benefits in scenario B are due to the reduction of the number of workers needed at the gates. This benefit explains near all the differences between the two technological scenarios. A relevant portion of the savings can be achieved by reducing the handling activities (48 % in Scenario A, 28% in Scenario B) and the workers involved in the controls (25% in Scenario A, 15% in Scenario B). Minor benefits are also due to savings in the use of fuel due to less idle and waiting time (6% in Scenario A, 4% in scenario B).

If we consider the total handing cost per TEU, active tags allow to a 4.3 % decrease of such costs, whereas electronic seals lead to a 7.5 % reduction (cf. Figure 4).

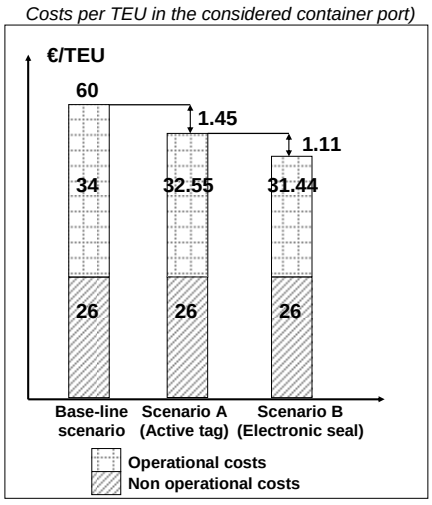

Figure 4: The costs per TEU

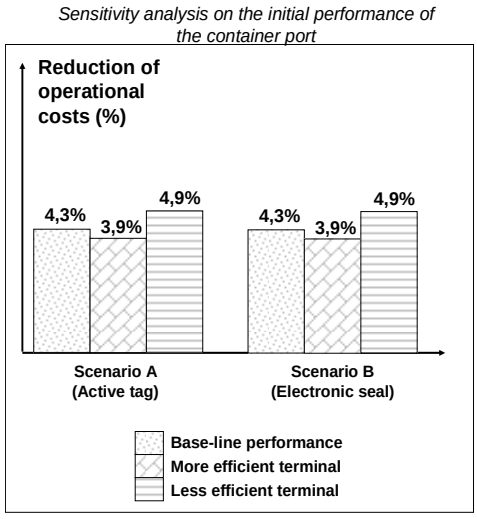

Figure 5: The sensitivity analysis

It is interesting to analyse how the operational benefits change when we consider a different base-line scenario. In particular, a sensitivity analysis has been carried out by considering different initial performances of the container port. The results of the analysis have been reported in Figure 5.

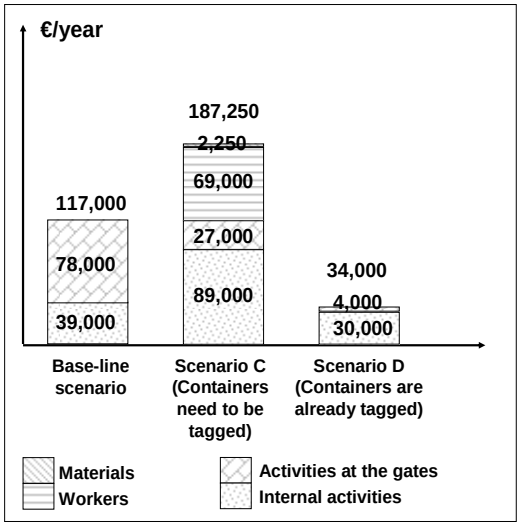


Figure 6: The costs per TEU

As for the analysis of the activities carried out by the Customs authority, only the import flow has to be considered. Figure 6 summarises the benefits in the two considered technological scenarios: scenario C differs from scenario D since it requires to tag the containers when they enter the terminal (cf. the technological scenarios).

If the containers need to be tagged when they enter the port, the operational costs significantly increase (+ 60%), whereas if the container have been already tagged it is possible to have a 70% reduction of the total operational costs.

The high costs in the scenario C are mainly due to the workers needed to tag the containers when they arrive at the gates, and the improved efficiency in the other operational activities are not big enough to compensate for these additional costs.

Much of the benefits gained in Scenario D can be reached thanks to the improved efficiency at the gates, which leads to a 95% reduction of this activity cost.

**The investments and the recurrent costs**

Under the assumption that the containers have already been tagged before, the investments that the terminal operator have to sustain are reported in Table 3. The Net Present Value and the Discounted Payback Period are also provided: they have been obtained using a discount rate of 7% and a reference period of 3 years.

| Scenario | Investments | Recurrent costs | Discounted Payback Period | Net Present Value |
|---|---|---|---|---|
| A (Active tag) | 277,400 € | 24,000 € | 2 years | 260,000 € |
| B (Electronic seal) | 312,000 € | 25,500 € | 2 years | 680,000 € |

Table 3: the investments sustained by the terminal operator

It can be observed that the initial investments – which include the hardware, the software, the installation costs, the building works and the project management – are lower than the total amount of benefits that can be reached every year. Taking into consideration also the recurrent costs, it is possible to obtain a discounted payback period of two years and a positive Net Present Value.

As for the Customs authority, instead, the return on the investments heavily depends on the technological scenario. When the containers have already been tagged before entering the port (Scenario D) a positive return on investments can be achieved, whereas this is not the case whether they have to be tagged at their arrival (cf. Table 4). This is due to the increased operative costs, since all the containers must be tagged at their arrival and the electronic seal must be taken away before the shipping (to re-use it).

| Scenario | Investments | Recurrent costs | Discounted Payback Period | Net Present Value |
|---|---|---|---|---|
| C (containers need to be tagged) | 154,000 € | 5,500 € | - | -341,500 € |
| D (containers are already tagged) | 41,500 € | 5,000 € | 1 year | 174,000 € |

Table 4: the investments sustained by the customs authority

**The non-operational benefits**

The use of RFId technology in a port environment can also lead to several non-operational benefits. The most relevant ones are briefly analysed in this section.

- increased productivity of the spreaders and improved service level: the reduced time needed for the handling activities leads not only to a reduction of the labour costs and fuel (evaluated in the operational model), but also to an increased productivity and to a better service level both to internal and external customers, which are more difficult to assess but not less important to consider. More in detail, using the queuing theory, a reduction of about 20% of the time spent by the container within the system has been assessed;
- environmental benefits: the time spent by the trucks waiting in queue at the entrance of the container port has been considered in order to evaluate the reduction of pollution that can be reached thanks to a reduction of the queuing times. The analysis carried out for the reference port shows that a reduction of about 2 hours of the time spent in the system can lead to a reduction of 0.2 tons of $CO_2$ in the annual emissions.
- intangible benefits: these benefits can easily be observed, but they are not easy to quantify. Some relevant intangible benefits that can be reached by using RFId technology are the followings: the automatic identification of the containers and ensuing fewer errors, the better container visibility and traceability, the increased security, the reduction of the contentious issues, the reduction of the illegal trade, the reduction of the variance of the total lead time and the reduction of the administrative costs.

## Conclusions

The automatic identification of the containers can lead to great benefits by quickening the handling activities and improving the resources productivity of both the terminal operator and of the Customs authority. By using an electronic seal it is also possible to reduce the time needed for the identification of the seal code, both at the arrival to the port and at the shipping. Moreover, the electronic seal is more difficult to counterfeit and it records when a violation takes place, so its use can help to prevent the container from being opened without authorisation. Thanks to the use of the RFId technology in all the supply chain (scenarios A, B, D) it is also possible to have a better visibility on the position of the container within the supply chain.
As expected, the greater benefits can be reached only if the RFId application is carried out at the supply chain level: a pilot application involving only one stage of the supply chain – that is the container port – does not show a positive return on investment, and it must be seen as an exploratory stage for the future, with the purpose of gaining experience on the technology and on the benefits that can be achieved.

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