Capacity Assessment Via Simulation for a Spanish Dry Port

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Abstract

The transportation industry is ever more concerned with sustainable developement, and intermodal transportation offers great advantages in that sense. Among the different sorts of terminals, dry ports are of particular interest. Actually, dry ports are closely related to both inland terminals and to maritime ones, since they share their structure with the former and are connected to the latter performing as inland enlargements of the latter, facilitating freight transportation. This work focuses on the performance of a dry port located in Coslada. For the purpose of the study a simulation model was developed and several likely scenarios were assessed

Key words: Intermodal, Combined Transport, Simulation, Terminal

1. Introduction

Intermodal transportation has demonstrated to be a rich field for the application of operations research and other techniques of quantitative analysis. A review of the processes which may be addressed, and the most suitable technique in each case, can be found in Gambardella and Rizzoli (2000). As they point out, among these techniques, simulation plays an important role providing an appropriate framework for decision-makers to assess solutions, sometimes provided by other techniques. Vis and Koster (2003) present a comprehensive review of applications devised to improve processes involved in intermodal terminals, categorized according to the purpose of the work, focusing on maritime terminals.

This study belongs to a series of works within the framework of a research line devoted to the development of simulation based tools to assist the decision making processes in intermodal transportation. Actually, the work presented in this paper is the continuation of a previous one, where a model of the Spanish railway combined transport network was designed. The aim of this model was to assist decision making related to facilities and operation policies, and consisted of a pool of inland intermodal terminals (road-railway transshipment) and maritime terminals (ship-railway transshipment), and the railway network connecting them (Garcia and Gutiérrez, 2003). Since the main focus of this work was the global performance of the network, some assumptions were made when modelling terminals which may not be appropriate when conducting a more detailed study.

Here, the authors undertake a more in-depth study of the modelling aspects of terminals, to build valid models for decision making at the terminal level. This work focuses on the performance assessment of a dry port under several scenarios, so that one may decide whether to acquire additional resources. To achieve that objective, a discrete event simulation model was developed and exploited. Although the model focuses on the particularities of a dry port (which is an inland terminal that works as an enlargement of maritime terminals), the designing guidelines might be transferred to other types of terminals.

The paper is structured as follows. In section 2, a rough description of how dry ports work is

presented and, more specifically, how the dry port at study works.
In section 3, the simulation model is described as well as the performance indicators/measures selected to assess the different scenarios. Following, in section 4, the experimentation conducted is summarised. Finally, section 5 contains the main conclusions of the work.

2. The dry port. Study objectives

The relevance of dry ports is highlighted within an environment where intermodality is becoming an ever more public concern.
Since the objective of a more sustainable development is closely related to transferring transport from the road to other means of transport, the interconnection of all available means is of paramount importance. But important though it may be, and despite governments and the Administration support, combined transport entails difficulties, such as coordination, which may account for its sluggish development.
A dry port is a type of intermodal inland terminal, which is connected to one or more maritime terminals, with the capability of postponing customs control at the entry of its facilities. This feature speeds up freight delivery from ports towards their destination points.
Spain has only recently included dry ports in its network and during the last few years several projects have been launched all over the country. Among them, the dry port in Coslada (Madrid), which has been working for some years now, is of high strategic value. Actually, railway combined transport has soared lately and in a country with the geographic characteristics of Spain, the maritime ports become key nodes for international freight exchange.
The main reason to choose this dry port is the fact that it is a representative instance of this type of facilities.
Besides, the dry port in Coslada (located on the outskirts of Madrid) has a strategic localization within the Spanish network (in the geographical centre of the Peninsula) and the high transportation needs of the region render this port a very appropriate and interesting case of study.
Finally, the physical proximity and the forthcoming attitude of the managers of the dry port, willing to cooperate and facilitate the necessary data were additional factors supporting this election.
The available resources involved in the operation of the terminal are the following ones:

- A gantry crane, to load and unload trains, and reachstackers, mainly to move containers from the loading/unloading area to the storage area and vice versa.
- A yard engine, which moves trains inside the terminal.
- Tracks for reception and departure, and tracks for loading and unloading the trains.
- Storage areas for containers and short term storage areas located by the loading and unloading rails.
- Container consolidation/deconsolidation centre.

With regard to the human resources, personnel working in the dry port belong either to a work team from RENFE (the Spanish railway company) or to a work team from the very terminal.
For the purpose of the study only 20 and 40 feet containers were considered.
First of all, although there exist units of transportation other than containters (such as swap bodies), most wares are stored in containers. And, secondly, although several sizes are available, most of them are either 20 feet or 40 feet.
RENFE owns the rolling stock in the dry port (the carrier wagons and the engines), and is also responsible for the management of these assets, which poses an additional constraint to the operation of the dry port, since some decisions are beyond the control of the managers in Coslada.

Figure 1. Areal sight of the dry port in Coslada

The layout of the dry port is shown in the picture of Figure 1, an aerial sight, where the physical elements can be identified.

With the only exception of customs control, all the operations in a dry port are exactly the same as those in an intermodal inland railway/road terminal. Following the pattern found in other similar models, such as in Kulick and Sawyer (2001) and Rizzoli *et al.* (2002), the basic operations modelled were the following:

- Unloading containers arriving to the terminal in trucks to be transported by train and, the opposite process, loading containers in trucks for their final transportation by truck.
- Loading outbound trains and unloading inbound trains.
- Customs procedures, in case they have not been previously done in the maritime port of origin.
- Container load manipulation in the consolidation centre, when required.
- Trains arrival and departure.

3. The simulation model features

The objective was to assess whether the facilities and the current level of resources could meet the future demand within different scenarios.

If not, some additional improvements of the level of resources should be analysed, so that the future demand could be met with acceptable levels of efficiency.

The study was twofold, namely, analysing both the dry port's effectiveness and efficiency in the different scenarios. In relation to the effectiveness, the main indicator was the total processing time for a container. The total throughput was of much less importance and therefore was not considered as a relevant indicator. However, to obtain a more detailed assessment of the system, the waiting time of containers in each operation can be valuable. With regard to the effectiveness, it was of great interest to identify potential bottlenecks and highly underexploited resources. Thus, the indicator chosen were: the use percentage of each resource (cranes and labour) and the average occupation of physical elements (such as rails and storage area).

The complexity of the system and the stochastic nature of the processes involved in the dry port are the common features of those problems studied through simulation. Discrete event simulation allows the researcher to create an off-line model where experiments can be run instead of doing it in the actual system, and more importantly, at quite a lower cost.

Among the range of simulation environments, Witness ® (by Lanner Group) was chosen to build the model with. Witness® has proved to be a suitable tool in studies of similar nature in the past and, actually, it was absolutely satisfactory for the current one.

When defining the conceptual model, the authors decided to take a step ahead in comparison to the previously developed models. Among the enhancements, those most worth mentioning are:

- Train length was flexible to some extent.
- The loading/unloading operations performed by the gantry crane were represented in a more realistic way.

Following, according to the information gathered from the dry port managers, the assumptions to obtain a valid model of the system are described.

First, combined transport trains run according to settled schedules, thus arrival and departure times were established and available.

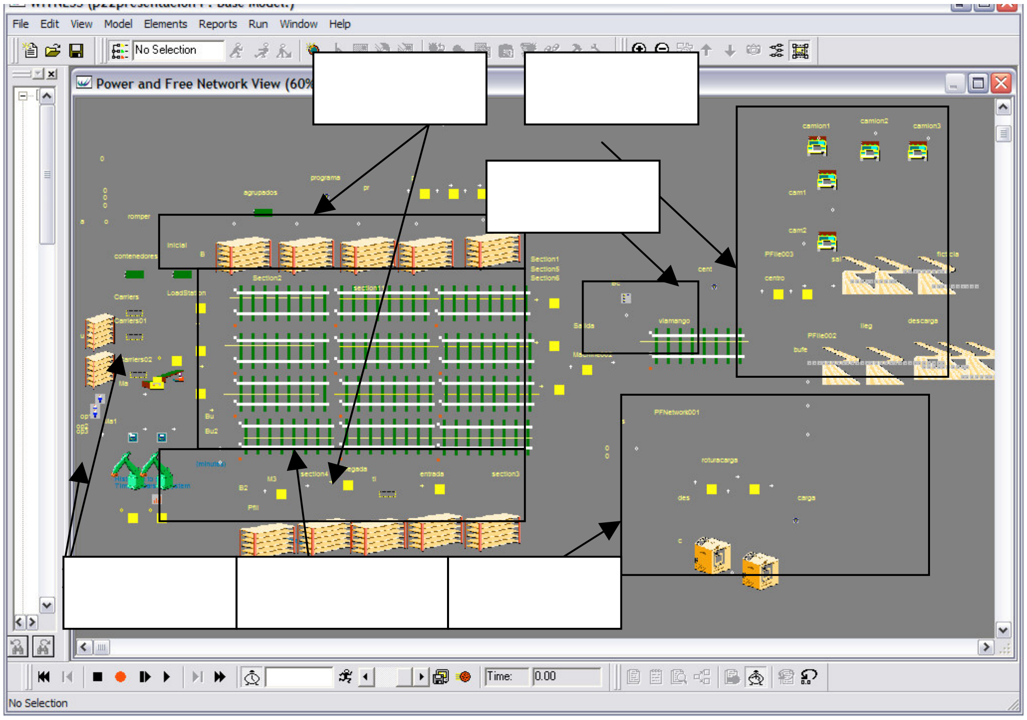

Figure 2. Screenshot of the model's display window

In particular, on average a train is shipped everyday to every destination and a train arrives every day from every origin, but on Sundays, where trains neither arrive nor depart. Destination/origin points are the ports located in Valencia, Bilbao, Barcelona y Algeciras.
As to the train length, the number of containers can not exceed a maximum number.
However, if the train is due to leave and if the number of already loaded containers is greater than a lower bound, it is allowed to depart even if it does not contain its maximum load. If the minimum loading condition applies but first condition does not, the train is allowed to depart as soon as it does.
Loading and unloading of containers onto the flat wagons are preferably carried on with the gantry crane, though if necessary reachstackers can be used as well.
Loading operations are considered to be of a higher priority than unloading ones, in order to allocate resources when conflicts arise. The loading process is launched at around two hours in advance of the planned depart time and is finished twenty minutes before that time. From that moment on, no loading of the train is allowed.

With regard to the containers coming from road transport, there is an unloading area where trucks park. Mobile cranes move to that area where trucks are unloaded. The container is carried either to the loading area (if its priority is urgent) or to the storage area (which occurs in most cases).
Those trucks arriving to the dry port and whose destination point is Madrid are loaded with a mobile crane, in the unloading area.
Those containers to be loaded to a truck (for regional delivery) can proceed from any of the following three sources: a recently unloaded container, the storage area or, finally, the consolidation/deconsolidation centre. In terms of the model, an attribute contained the value describing the origin of each container.
Finally, the stochastic nature of the model is embedded, mainly, in the following elements. First, there is probability according to which containers are labelled as urgent; the number of containers that ought to undergo a redistribution process; and the failure rate of cranes involved in the loading/unloading operations.
The image in figure 2 is a screenshot from the display of the model, where the most relevant components of the model can be identified.

Once the model had been programmed and carefully verified, a first set of experiments was conducted, where the model represented the current configuration of the system. More specifically, five replications were done, with a replication length of a week. The initial state of the model was obtained from de actual data of the system, provided by its managers.

The results from these experiments were compared with the data gathered from the dry port managers and contrasted with them. The model proved to be a valid for the purpose of the study.

5. Computational results

Current situation

According the analysis of the current situation, the main conclusions that can be drawn from the study are the following ones:

- Those resources involved in moving freight are idle for roughly 40% of the time.
- The system can handle a greater number of trains, but this is not occurring due to the number of scheduled trains.
- The quality service is not too high, since the containers' average time in the system is 3.7 days. The explanation of such a high figure is, again, the number of scheduled trains and the fact that this dry port serves as temporary storage facility for the maritime ports it is connected to, since the lack of storage capacity in those ports.

According to these results, a significant improvement in the dry port performance could be attained if the institution in charge of setting the number of trains and their schedules (which is RENFE) increased the allocation of this sort of resources to the system.

Scenario 1

Consistently with the growth expectancy for the following year, a future scenario was considered. This first scenario differed from the current situation in the demand, a 30% greater than the current one. This leap is reasonable, since the dry port started its operation in 2000 and is still in its initial phase.

As an assumption to this scenario, the number of trains was supposed to grow in the same amount as the demand.

In this case, according to the simulation, the system was expected to perform as follows:

- The resources involved in moving freight are busy at around 80% of the total time.
- With that use percentage the dry port can perfectly meet the demand, no trains or trucks are unattended in this scenario, which means total effectiveness.
- Besides, average waiting times decrease. For example the total time a container spends in the system till shipped is 3.3 days. This result is not surprising, since as the demand grows and the resources are not still overloaded, the greater number of trains yield that reduction.

Scenario 2

The last scenario under study was characterized by a demand level equal to its maximum estimated level: 140 trains per week (70 in and 70 out), which represents almost a threefold increase of current level of resources.

In case that demand grew to that extent it would no longer be realistic to keep the shift pattern as it currently is. For the sake of realism, in this second scenario the dry port is supposed to work round the clock in three different shifts.

The expected performance of the system in this case can be summarized as follows:

- The resources involved in moving freight are busy at around 90% of the total time.
- Besides, waiting times decrease to an average of 2.5 days, which means a higher quality service.
- On average, seven trains are unattended, which in relative terms represents a 10% of ineffectiveness. This result is not inconsistent with the level of idleness of the available resources, due to the fact that trains, though previously scheduled, might not arrive with a pattern which allows a balanced utilization of resources.

Usage percentage	Current situation	Scenario 1	Scenario 2
Gantry crane	47% *	74% ±1%	87% ±2%
Reachstacker 1	63% ±5%	84% ±4%	89% ±3%
Reachstacker 2	63% ±6%	83% ±4%	89% ±3%
Labour 1	66% ±5%	86% ±3%	87% ±6%
Labour 2	59% ±6%	82% ±4%	85% ±2%
Labour 3	47%	75% ±1%	85% ±2%
Tracks	100%	100%	100%

Table 1. Efficiency indicators

Indicator	Current situation	Scenario 1	Scenario 2
Avg. num. of 40-feet cont. in the storage area	529 ±11	602 ±12	629 ±33
Avg, waiting time in the storage area (min.)	5610 ±30	5040 ±10	3600 ±66
Unattended trains	0	0	7
Avg time in the storage area (including urgent ones (min.)	5300 ±30	4800 ±10	3600 ±57

Table 2. Effectiveness indicators

As an overall conclusion with regard to the computational results, the dry port is expected to meet the demand both in the short and the medium term. Were there more containers available the system could offer a higher level of quality service, although this decision is beyond the dry port managers' responsibility. Besides, in the current operating conditions and working on a 24 hour/day basis, if the demand reached its maximum potential value, there would be some shortage of resources and some trains would not be attended. In case the managers desired to overcome this ineffectiveness operating as the dry port does now, it would be necessary to acquire some additional assets, to the detriment of the efficiency (since a higher lever of idleness would be expected).

6. Conclusions

An example of a simulation study to carry on a quantitative analysis of the performance of a intermodal terminal of a particular nature (a dry port) has been presented. The same methodology applied to similar studies has been successfully used, introducing the appropriate modifications to represent the particularities of the system at study. Besides some improvements have been included, being the variability of the train length (between a lower and an upper bound) and the more accurate representation of the loading/unloading processes by means of using a gantry crane.

The model, verified and validated, has allowed the prediction of its performance in two plausible scenarios, and asses this performance in terms of quality service and resource utilisation.

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