A Dwell Time-based Container Positioning Decision Support System at a Port Terminal

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Abstract: In this article, a methodology as well as a decision support system for the container storage assignment at a yard of a container terminal is proposed. The motivation of the proposed methodology are the cases of container terminals where inland flows present high levels of uncertainty and variability. This situation is typical of ports in developing countries such as is the case in Latin America where due to lack of automation, there are many paper-based procedures and little coordination with the hinterland. The proposed methodology is based on a dwell time segregated storage policy, considering only import containers (due to the difficulty to determine segregation criteria for this type of containers). Dwell times are discretized in order to determine dwell time classes or segregations, so that containers of the same segregation are assigned to close locations at the yard. As a case study, the port of Arica in Chile is considered. A discrete-event simulation model is also proposed to estimate potential benefits of the proposed methodology. Numerical results for the case study show a good performance, with potential reduction of the rehandles incurred.

1 INTRODUCTION

World container port throughput increased by an estimated 5.1% to 651.1 million TEUs (twenty-foot equivalent units) in 2013 and global containerized trade was projected to grow by 5.6% in 2014 (UNCTAD, 2014). Maritime ports are strategic nodes on the international logistic chain whose current role goes beyond the traditional functions of transferring cargo to a more active participation and promotion of value-added services to the port stakeholders. Ports can be conceptualized from a logistics and supply chain management approach and under this vision the traditional port system is extended to an "integrated channel management system" where the port is a key location linking different flows and channels with the port community (Bichou and Gray 2004). In this context, efficient cargo handling operations are essential, as new value-added services, as well as better service levels, agility and predictability are demanded by the users of the port. The productivity of a container terminal is related to an efficient use of labor, equipment and land, and is commonly measured as a function of the ship turnaround time, the transfer rate of containers and the dwell times of the cargo at the port (Dowd and Leschine 1990; Doerr and Sánchez, 2006; Chung, 1993).

At the port, the yard can serve as a buffer between the arrival and departure of temporarily stored cargo which is later loaded on a ship or dispatched to external carriers. The efficiency of the operations at the yard significantly impact ship turnaround times so adequate container storage space assignment policies and yard equipment planning are needed. In addition, minimizing port dwell times is one of the main objectives from the perspective of the shippers in the port supply chain (Lee et al. 2003).

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Coordination of landside operations at a container terminal is not straightforward in ports in developing countries where there are important challenges in terms of infrastructure development, technology implementation and paper-based documental procedures. Latin American and Caribbean (LAC) ports have seen an important increase in their participation in world foreign trade. This growth has put pressure on the freight distribution systems that need to develop better logistics capabilities (Rodrigue, 2012).

In this article, the problem of defining a container storage space allocation policy for import containers is addressed by considering the case of a container terminal that faces a high level of uncertainty in the dispatching process of import containers. This uncertainty is mainly explained by the lack of coordination mechanisms with the hinterland, a situation that can be very common at ports in emerging countries.

The assignment of space at the yard for export containers is not considered in this article. The reason is that yard planners of container terminals have general criteria to group export containers into segregations (e.g., vessel, port of destination, weight, etc.), while for import containers is more difficult to determine. This is explained as the time in which the containers are retrieved depends on the different consignees of the cargo (importers) and the fulfilment of all the procedures, resulting in more uncertainty. In contrast, export containers are loaded to a single vessel at the container terminal.

During the dispatching of an import container, it is possible that other containers may be blocking the container and should be removed to be able to reach the required container. These non-value added movements are refereed as “rehandles” or “reshuffles” of containers. Rehandles represent a high cost with no value for the container terminal, and increase the truck turnaround times of the external trucks at the container terminal, generating congestion and affecting service levels of to the users of the container terminal.

In order to assign a storage space for the import containers in the yard, a dwell time segregated storage policy is proposed. In this case, segregations of import containers are defined based on dwell time intervals, and containers of the same segregation are assigned to close locations. The aim is to reduce potential container rehandles at the moment that they are retrieved from their locations at the yard. Hence, containers with the same interval of dwell time located at close positions in the yard, may incur in less rehandles. In order to estimate dwell times of import containers, classification algorithms are employed. This is justified as the results of the estimations are used to define import container groups based on dwell time ranges so the precise values of the predicted dwell times are not needed. In addition, the design of a decision support system for the assignment of storage space to import containers is proposed. The aim is to assist the yard planner with a tool that may be inter-connected with the Terminal Operator System (TOS) of the container terminal.

As a case study, the container terminal at the port of Arica in Chile is considered. High levels of uncertainty for import container dispatching as well as long dwell times are observed in the container terminal due to the type of cargo handled; around 70% of the cargo is in-transit from Bolivia. The political agreement between Chile and Bolivia establishes special conditions for the in-transit cargo where no storage fee is charged. The current practice of the yard managers is to assign space to containers in a semi-random fashion where containers are located at the yard considering only the space utilization rules that have been set to avoid unutilized space.

In order to validate the methodology proposed in a stochastic environment, a discrete-event simulation model was implemented, to determine the potential impacts in terms of rehandles of containers when are retrieved to be dispatched to external transport carriers.

The article is structured as follows: Section 2 presents a literature review, Section 3 describes the methodology employed and the proposed dwell time segregated storage policy. Section 4 presents the architecture and components of the decision support system for the storage space assignment of import containers. Section 5 presents the case study as well as the simulation model to estimate the benefits of using the proposed support system to assign storage space to import containers. Conclusions and recommendations for further research are provided in Section 6.

2 LITERATURE REVIEW AND BACKGROUND

2.1 Main Contributions Related to Dwell Time Estimations in the Literature

Carlo et al., (2014) presents a review on storage yard operations at container terminals, providing an

overview, trends and research directions. Several contributions have been proposed, both from the perspective of the design of the layout of the yard, storage space policies and stacking algorithms. In this section, we focus the attention on reviewing the main contributions to dwell time estimations in the literature, which is more related to port terminal capacity and the storage space policies of the port terminal.
Port terminal capacity is defined as the amount of cargo that can be handled by a port per time period (Bassan 2007). The first contributions related to capacity analysis at the yard of a Container Terminal are presented by (Dally 1983; Hoffman 1985; Dharmalingam 1987), where storage capacity at the yard is estimated as a function of container dwell times, the number of stacking containers, and the container storage space available expressed in TEUs, among other factors.

Determining the factors that influence port choice and port competitiveness is another research avenue where cargo dwell times are identified as an explanatory variable (De Langen 2007; Nir et al. 2003; Tongzon and Sawant 2007; Veldman and Bückmann 2003). Arvis et al. (2010) identify dwell time as a factor that directly affects operational costs in the ports as it increases inventory levels and uncertainty in the dispatching process. On the other hand, dwell times have also been identified as an element of port competiveness and a factor in port choice related decisions (Magala and Sammons 2008).

From a macro-economic perspective, the impact of port delays at Puerto Limón in Costa Rica, over the regional economy in Central America is estimated in (USAID, 2015). They conclude that reducing port inefficiencies, such as long dwell times of cargo at the ports, may improve the GDP (Gross Domestic Product) of Costa Rica by about 0.5%. Djankov et al. (2006) employed a gravity model to estimate the impact that each additional day required for dispatching cargo may have on the GDP. The unproductive movements undertaken during quay transfer operations are quantified by Chen et al. 2000. They identify storage density as a factor of unproductive movements during ship loading and unloading operations. This refers to the number of containers stacked in the yard and the ground slots used for storage. Furthermore, their results show that housekeeping moves represent the majority of unproductive moves undertaken.

Merckx (2005) estimates dwell time impact on the capacity of a terminal based on a sensitivity analysis, considering five scenarios with different dwell times and container types. The interaction among the terminal operators and the users of the port (e.g. importers/exporters, freight forwarders) is analyzed by Rodrigue and Notteboom (2009) and they conclude that the relationship and collaboration levels could impact container dwell times at the port.

An analysis of dwell times at ports in Sub-Saharan Africa is presented by Raballand et al. (2012). Main findings highlight that dwell times are abnormally long, more than 2 weeks, and also show an abnormal dispersion which increases the inefficiencies of port operations and, in consequence, total logistic costs. Beuran et al. (2012) provide an analysis of the causes of these long dwell times from the shipper perspective, discovering the crucial importance of private sector practices and incentives.

Moini et al. (2012) analyze the factors that determine container dwell times in a port, employing three data mining algorithms: (i) Naive Bayes Algorithm (Kononenko 1990), (ii) Decision Tree C4.5 (Quinlam 1986) and (iii) The Hybrid Bayesian decision tree (Kohavi 1996). Estimation results are compared in terms of four indicators: accuracy, the Kappa coefficient, RSME and execution times. In order to evaluate the results they provide a simulation under different scenarios with the results obtained. An important difference with respect to the work presented herein, is that the authors do not use the results to estimate container storage assignment policies. In addition, the data mining algorithms also differ from those proposed in this article.

Another contribution of the work presented here, is the discretization of a continuous variable (dwell time) for its prediction, justified by the fact that the results are employed as criteria to segregate import containers and assign storage space according to this policy. In contrast, Moini et al. (2012) do not employ classification algorithms in their approach, which is reasonable as their aim is not to determine storage space policies which is an important difference with respect to the work presented here. Finally, another contribution of this work is the simulation proposed model that aims to measure the impact of different storage policies in terms of the number of rehandles incurred when containers are dispatched to external carriers. It is important to point out that in the literature there is no approach proposed in which the input data of a simulation model consists of the results obtained by the classification algorithms for dwell time estimation.

2.2 Determinant Factors of Dwell Times

Table 1: Main Determinant Factors of Dwell Time.

Factor	Reference	Type
Frequency of the sailing schedules of the vessels	Merckkx (2005), Moini *et al.* (2012)	Unique Value
Type of container (e.g., empty/full, dry/reefer, etc.), size (20/40 TEUs) and its contents	Merckkx (2005), Moini *et al.* (2012)	Nominal
Modal split of hinterland connections	Merckkx (2005), Moini *et al.* (2012)	Unique Value
Port Governance and structure	Merckkx (2005), Moini *et al.* (2012)	Unique Value
Location of the Port Terminal and the main products (or logistic chains) that are transferred.	Merckkx (2005), Moini *et al.* (2012)	Unique Value
Terminal working hours and business days	Merckkx (2005), Rodrigue and Notteboom (2009), Moini *et al.* (2012)	Unique Value
Shippers and consignee	Rodrigue and Notteboom (2009), Moini *et al.* (2012)	Nominal
Inspections and regulatory procedures	Moini *et al.* (2012)	Unique Value
Transport corridors	Moini *et al.* (2012)	Nominal
Ocean carriers or Maritime Shipping Company and the demurrage time for the empty containers	Moini *et al.* (2012)	Nominal
Container flow balance (export and import)	Moini *et al.* (2012)	Nominal
Freight Forwarder/Broker and Third Party Logistics Company (3PL)	Moini *et al.* (2012)	Nominal

The main factors considered in the literature as dwell time determinants are presented in Table 1. The factors are divided into two groups: unique value and nominal value. Factors with a unique value are those that may have a unique value at each port and this value does not vary as a function of the cargo transferred at the port (i.e., the frequency on the itineraries, the location of the port terminal, etc.). This type of factor is not considered as the results for predicting dwell time are employed for container space allocation policies and this is influenced by the amount of cargo handled. On the other hand, nominal and numerical factors correspond to factors that vary as a function of the cargo handled, where nominal factors are represented by strings and numerical factors by a number. For instance, a nominal factor is related to the name of the importer or exporter, while the weight of a container is a numerical factor.

3 METHODOLOGY DESCRIPTION

The dwell time segregated storage space policy is based on generating segregations of import containers based on dwell time intervals. In this way, containers of the same segregation are those whose dwell time is predicted to be at the same interval. In order to determine the dwell time classes and estimate the potential impact of the proposed storage space policy, the proposed methodology is described as follows in Table 2.

Table 2: General Methodology.

DWELL TIME BASED STORAGE SPACE POLICY CALIBRATION

INPUT: Data Base with Historical Data on the arrival and departure time of import containers

1. **STAGE 1:** Dwell time prediction by classification algorithms
   - 1.1. Class definition as a function of time intervals in order to discretize the dwell time numerical variable.
   - 1.2. Application and validation of the classification algorithms based on a predictive model.
   - 1.3. Identification of the interrelation among the dwell time measure units based on a multi-classifier generation.
   - 1.4. Performance evaluation of the classification algorithms.

2. **STAGE 2:** Dwell time segregated storage policy implementation and evaluation
   - 2.1. Segregate containers based on the dwell time classes obtained in Stage 1.
   - 2.2. Run the simulation model for a set of instances, testing the performance in terms of the number of rehandles when containers are retrieved. Compare results with alternative storage policies that may resemble the current practice of the container terminal under study.

Output: Policy and impact estimation if dwell-time segregated policy is implemented.

3.1 STAGE 1: Dwell Time Prediction by Classification Algorithms

As observed in Table 2, the first stage consists of applying classification algorithms to predict dwell times. For this, it is necessary to have a data base with historical data about the containers' arrival and departure times at the yard. Step 1.1 is related to the class interval definition. We consider that the classes may be measured in three time units: hour, day and week. Table 3 presents a more detailed description of Step 1.2.

For the sample size definition, the formula to be used is provided by Cochran (1986), in which the size of the population is assumed to be an input data. For the classification model, different classification algorithms can be evaluated according to the specific characteristics of the container terminal under study. In addition, Step 1.3 consists of the definition of the multi-classifier to determine the inter-relations among different dwell time measure units. Step 1.4 consists of an evaluation of the results obtained by the different classification algorithms. Four performance metrics are considered: (i) the number of instances classified correctly, (ii) the Kappa coefficient, (iii) the computational time and (iv) the mean squared error in time units (Witten et al. 2011).

Table 3: Classification algorithms based on a predictive model.

Step 1.2 Classification algorithm application and validation
INPUT: Data base with historical data on the arrival and departure times of import containers 1. Sample size definition 2. Random sample of instances 3. Definition of the classification model 4. Evaluation of the classification model 5. Estimation of the prediction error **Output:** Dwell time predictions.

3.2 STAGE 2: Dwell Time Segregated Storage Policy Implementation and Evaluation

A common practice of terminal operators is to assign space to containers at the yard based on segregations. In order to determine segregations of import containers based on dwell time intervals, the predicted dwell times and intervals found in stage 1 (see Table 2) are employed for an instance of the container terminal under study. Then, a real time stacking heuristic for locating the import containers in each dwell time segregation is defined, so that containers of the same segregation may be assigned to close locations with the aim of reducing rehandles when containers are retrieved.

In order to evaluate the benefits of implementing the policy at the yard, a discrete event simulation model is also proposed, in which the dwell-time storage space policy is implemented to define the location of the import containers at the yard. The dispatching process of the import containers to external carriers is also simulated in order to count the number of rehandles incurred. More details will be provided at section 5 with the case study.

4 DECISION SUPPORT SYSTEM FOR THE ASSIGNMENT OF STORAGE POSITIONS TO IMPORT CONTAINERS

This section details the architecture of a decision support system for the container position assignment at the yard of a container terminal. The aim of the system is two-fold: First, we enhance the capabilities of the TOS with a module that predicts the dwell time based on historical data. Second, we take advantage of that prediction in order to suggest an explicit storage location for the container under scrutiny.

When an import container is unloaded from the vessel and is transported to the yard, the yard planner examines the container and faces the decision of where to store it. The yard planner uses the proposed system to estimate the dwell time based on characteristics associated to the container and historical information of other containers stored in the yard. As opposed to expert intuition, this estimation can be used to make an informed decision. If the yard planner desires, the system can suggest a specific storage location for the container.

When a container is assigned to a particular storage slot at the yard, it is stored until requested by the consignee. There are some cases in which the container may be relocated because it is blocking the access to the yard crane to retrieve another container. These movements are also referred as rehandles. One of the objectives of the yard planner, is to reduce the number of rehandles or relocations of containers, as these are non-value movements that generate additional costs and waiting times.

The storage space at the yard is organized as a three dimensional matrix ordered in bays, columns and rows (see Figure 1 for a pictorial reference). This abstract representation is convenient for maintaining an internal representation of the current state of the storage space. It is possible to define algorithmic operations for assigning a slot to a container, requesting the coordinates of a particular container, and analyzing if there is more containers on top of the requested item (i.e., a container), and so on.

In order to explain the details of our proposed architecture, we will describe a sequence of temporal events and the relationship with each particular module of the system. Figure 2 depicts the software architecture for the above-mentioned decision support system. This system is constituted by one main module that is connected to the TOS. The TOS corresponds to a software suite designed to manage the resources of the container terminal and it can be an in-house developed software or a generic commercial product (e.g.,Navis N4 TOS).

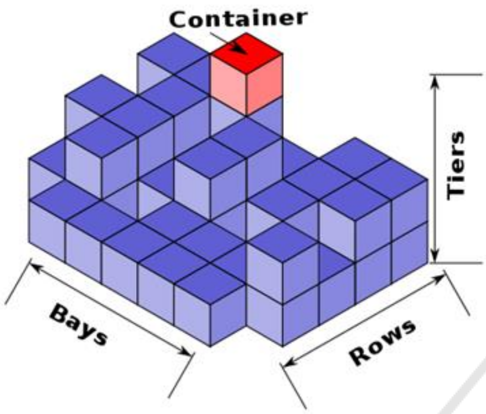

Figure 1: BAROTI System.

The whole process begins when the import container arrives to the port. At that moment, the yard planner accesses the graphical user interface (GUI) to identify the container that must be stored (labelled with the number 1 in the Figure 2). Then, the system connects to the TOS, retrieving statistical information regarding the container such as the name of the consignee, the service or vessel, type of container, weight, etc. This information is fed to the predictor and an estimation for the dwell time is obtained (see number 2 in the Figure 2). This estimation is made based on a mathematical model that use the historical data of containers and dwell time kept in the Container database. The planner use the dwell time estimation to decide where to place the container.

Alternatively, the planner may request to the system a recommendation for the location of the incoming container to the yard. For this matters, the system includes a special module that may suggest to the yard planner, a storage position at the yard (see label 3 in the Figure 2). The module internally ask for a dwell time prediction, which is used as the input for an internal algorithm that outputs a location. This output location is assumed to be the best option for storing the current container. The general assumption is that two containers with a similar dwell time must be located in neighbouring regions. In contrast, two containers with a big difference in their dwell times, are assign to different locations avoiding to interfere to each other.

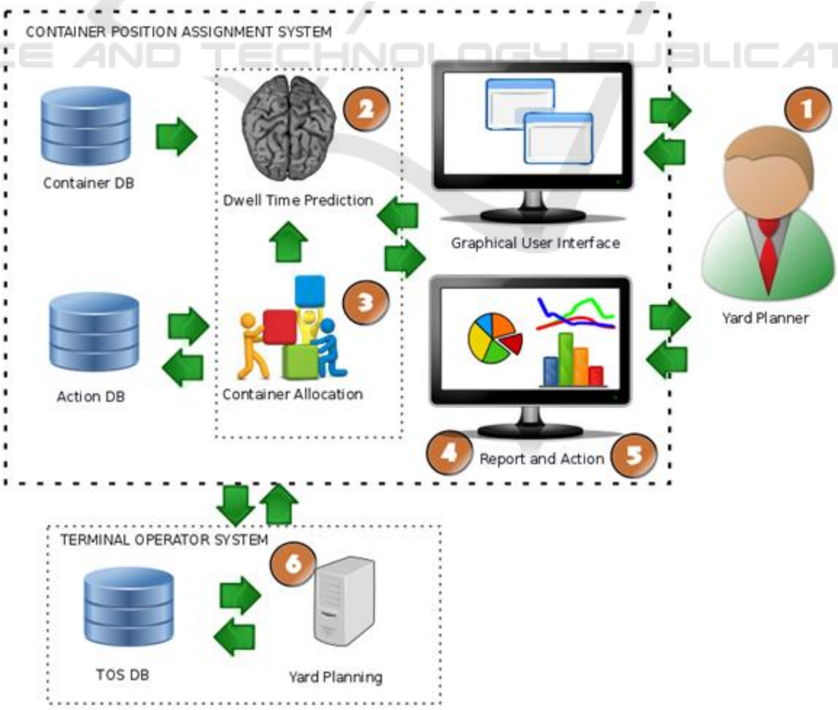

Figure 2: Container Position Assignment System architecture.

Once the dwell time prediction and/ or the storage position of each incoming container at the yard have been determined, the system generated a report with this information. This report may include a graphical representation of the yard. In this report, the location in which the current container must be assigned is specified (label 4 in the Figure 2). Based on this information the yard planner may decide whether to accept to locate the import container in the suggested position. This action (label 5) is recorded in the *Action Database*. Here, our idea is that the learning system is generating solutions for the problem and the human expert can validate them as being correct or wrong, knowledge that can be further exploited to refine the learning method of the system.

Finally (label 6), the decision made by the yard planner is communicated to the TOS, which records the transaction. As a final comment in this matter, we observe that the architecture is not limited for a single user. Rather, more than one yard planner may access the service concurrently, which can be an advantageous feature, as this information for instance, could be provided to the yard crane operators in a mobile device.

5 CASE STUDY: PORT OF ARICA IN CHILE

The port of Arica, Chile is used in this case study because it presents a high level of uncertainty in the import processes and huge container dwell times. The port of Arica occupies the 43rd position in the Latin American containerized movements ranking provided by UN-ECLAC; and the 6th position in the Chilean port system, with a total of 204,174 TEUs transferred in 2013 (Doerr 2013). The port consists of a single multi-purpose terminal whose main characteristic is that about 70% of the cargo corresponds to cargo in transit from Bolivia. The port presents special conditions for cargo handling, due to the political agreements between Chile and Bolivia, a reason for which the cargo has no storage fee (exports for 60 days and imports up to 365 days). Furthermore, the main hinterland (located in Bolivia) is more than 1000 kilometers away, in contrast with the main Chilean ports, Valparaiso and San Antonio, whose main hinterland (Metropolitan Region of Santiago) is located at 120 kilometers from the ports.

The port of Arica lacks coordination of systems with the hinterland such as appointment or booking systems, or electronic data interchange. This fosters the uncertainty and variability in port operations, especially for the import processes. Long service times (truck turnaround times) and container rehandles are commonly observed. Under this situation, the current practice of the yard managers is to assign space to containers in a semi-random fashion, where containers are located at the yard considering only very simple rules that maximize space utilization. A segregation-based policy for storage space assignment of export containers has been an efficient strategy for reducing rehandles incurred when containers are loaded on the vessel. Segregating export containers is commonly done based on the vessel´s characteristics and the corresponding route. These characteristics are considered when the stowage plan is generated and hence, rehandles are potentially minimized. In contrast, the criteria for segregating import containers are not so straightforwardly determined, especially if high levels of uncertainty on the dispatching times are observed.

In this paper a methodology to implement a dwell time segregated policy for assigning space to import containers is proposed. The policy considers segregating containers based on predicted dwell time intervals. In order to evaluate the different classification and multi-classification algorithms employed, the following metrics have been considered: (i) number of instances correctly classified, (ii) accuracy, (iii) Kappa´s coefficient; (iv) the mean squared error; (v) the mean error in time units" and (vi) the mean error for categorized factors.

A data base with container movements for the years 2011, 2012 and August 2013 is included, with a total of 151,640 import containers. Seven factors were considered: (1) size of the container (20/40), (2) type of container (Dry, Reefer, High Cube, etc.), (3) the status of the container (full or empty), (4) weight, (5) ship where the container is unloaded, (6) consignee or customer, and (7) the cargo's port of origin.

The first four factors correspond to characteristics of the container. The factors are numerical (size of container and weight) and nominal (type, status, ship, port of origin, consignee). The only dual attribute is dwell time, and the nominal variable consignee has the largest number of classes (about 5000 to 7000). It is important to mention that the weight and port of origin are factors not previously employed in the literature (see Table 1).

5.1 Results Obtained with the Classification Algorithms

For the classification model, non-supervised classification algorithms were employed as they allow working with known classes. These algorithms follow an opposed strategy than supervised algorithms (Astudillo et al. 2014; Astudillo and Oommen 2014). This is justified by the fact that classes are known, since they are determined in the step 1.1 of the proposed methodology (see Table 1). The applied offline algorithms are Naive Bayes, Lazy Learning, and Rules Induction Learning. Table 4 summarizes the classification algorithms evaluated:

Table 4: Classification Algorithms evaluated.

Algorithms	Reference
K *nearest neighbors* (KNN)	Cover and Hart (1967)
Naive Bayes (NB)	Kononenko (1990)
One Rule (OneR)	R.C. Holte (1993)
Incremental Reduced Error Pruning (IREP) or *Repeated Incremental Pruning to Produce Error Reduction* (RIPPER or JRip)	Fürn Kranz (1994)
K*	Cleary and Trigg (1995)
Decision Table (DT)	Kohavi (1995)
Zero Rule (ZeroR)	Witten and Frank (2000)

Dwell times were measured in days, as this is the commonly used time unit in port Terminals. The year 2011 data was used to generate the model and the 2012 data was used to evaluate it. Data for 2013 was used only for the simulation model described in section 4.2. The algorithms were implemented in JAVA version 1.6.0_25, using the software WEKA (Waikato Environment for Knowledge Analysis) in a personal computer with a processor Intel Core 7, and 8 GB of RAM.

Table 5 summarizes the results found with each algorithm. The classification algorithm that obtained a larger number of correctly classified instances, best accuracy, Kappa´s coefficient values and root mean squared error is the K*. The JRip algorithm obtained the best error values. On the other hand, the K* algorithm had longer computational times (twice as much as JRip).

A multi-classifier algorithm for dwell time predictions was also proposed, and it was trained using the information from the historical data base. Results are presented in Table 6, where it can be observed that the KNN algorithm obtained the larger number of correctly classified instances, accuracy and error values, with a computational time of 40 seconds.

As observed in previous tables, the algorithms without the multi-classifier obtained better results in general. On the other hand, the accuracy values are always lower than 10%, which is explained due to the variability of the ship and consignee factors in the data base. For dwell time predictions, the average error is about 7 days, which is high, but under current operations, managers of the port of Arica are not able to estimate container dwell times, hence in the long run, it is expected that this number can be reduced.

5.2 Impact Assessment of the Proposed Policy via a Discrete Events Simulation Model

A simulation model of the import processes at the port of Arica is proposed in order to evaluate the impact of the storage policies in terms of the number of rehandles incurred. For comparison purposes, a storage policy was implemented considering two variants of the stacking strategy of containers without the dwell time segregation policy. This allows to emulate the current practice of the port managers.

Table 7 outlines the general procedure for the general stacking strategy implemented based on the dwell time segregations policy. Table 8 outlines the procedure for the non-segregation storage policy that employs two stacking strategies: Semi-random and Sequential, which are illustrated respectively in Figure 3 and Figure 4.

The instance implemented considered the movements of containers in the years 2012 and 2013. The yard of the port terminal consists of 19 blocks for import containers with a total of 4820 TEU slots. In order to predict the dwell times, the JRip and multi-classifier algorithms were implemented. The real arrival of containers at the port during each year is taken from the data base. For the random stacking strategies, five replicates were run. For the sequential stacking strategies, no replicates were tested given that the solution obtained is the same since the arrival of containers does not change. For the random stacking strategies standard deviation values were in the range of 140 to 444 rehandles. The simulation model was implemented in the software ExtendSim OR version 9.0 and run in a personal computer with Intel Core 7 and 8Gb RAM. Table 9 presents the results obtained.

Table 5: Results obtained with the classification algorithms.

Algorithms	Number of correctly classified instances	Accuracy	Kappa´s coefficient	Mean squared error	Rootmean squared error	Computational Time (seconds)	Error (days)
Naive Bayes	3,875.8 ± 188.4	6.77%	0.031 ± 0.002	0.058 ± 0.000	0.069 ± 0.000	34.1 ± 2.9	7.88 ± 0.67
OneR	2,365.9 ± 103.3	4.13%	0.019 ± 0.003	0.058 ± 0.000	0.098 ± 0.000	34.1 ± 3.9	8.51 ± 0.20
ZeroR	2,942.3 ± 167.6	5.14%	0.000 ± 0.000	0.058 ± 0.000	0.068 ± 0.000	62.4 ± 4.9	8.21 ± 0.93
Decision table	3,254.6 ± 256.3	5.68%	0.013 ± 0.005	0.058 ± 0.000	0.068 ± 0.000	**27.4 ± 1.6**	7.12 ± 0.44
K*	**4,116.7 ± 88.1**	**7.19%**	**0.038 ± 0.002**	0.058 ± 0.000	**0.067 ± 0.000**	109.0 ± 3.4	7.42 ± 0.10
KNN, K=1	3,966.6 ± 135.2	6.93%	0.035 ± 0.002	0.058 ± 0.000	0.070 ± 0.000	31.1 ± 10.5	8.07 ± 0.17
JRip	2,760.6 ± 164.1	4.82%	0.002 ± 0.001	0.058 ± 0.000	0.068 ± 0.000	36.6 ± 4.1	**6.94 ± 0,88**

As observed in Table 9, the average number of rehandles incurred for both 2012 and 2013 are always lower for the segregated dwell time policies employing any type of stacking strategy. Furthermore, the gap between the average number of rehandles for the non-segregated and segregated policies is around 13%. Comparing the best stacking strategy in each period for the segregated and non-segregated policies, a 6% and a 37% gap were obtained for the 2012 and 2013 periods respectively.

In order to estimate the economic impact of the dwell time segregated storage policy, the period between January and April 2012 is considered. A total of 16,867 rehandles were incurred at present conditions. If the dwell time segregated and sequential stacking strategy is employed, the total number of rehandles incurred is 14,051, with an approximate 17% reduction. If the cost of each rehandle is estimated as 10 dollars, it represents potential savings of about USD $28,000 for the container terminal.

For further implementing the proposed decision support system, the port terminal requires to develop a module that may be interconnected with its TOS. It will be necessary that the port terminal develop a historical data base (Container DB in Figure 2 in section 4) with the characteristics of import containers that have been stored in the yard for at least 2 years and update periodically this database or in real time. The information required considers the characteristics of containers, its cargo, and destination in the hinterland, as well as the dwell times. This information will be the input data for the prediction system. It will be also required to maintain a data base registering the decisions taken by the yard planner in order to analyse the performance of the proposed system.

We estimate that implementing the proposed support system will not alter the current operations of the port terminal, and is not intended to replace the yard planner tasks. The aim of the proposed system is to support yard planner decisions and derive recommendations that will make easier this job and may lead to more efficient operations in the long run.

Table 6: Multi-classifier results.

Algorithms	N° of correctly classified Instances	Accuracy	Computational Time (seconds)	Error (days)
Naive Bayes	3,226.9 ± 122.6	5.63%	79.9 ± 1.5	7.47 ± 0.20
OneR	1,309.6 ± 87.9	2.28%	**19.4 ± 0.9**	8.75 ± 0.25
ZeroR	3,216.4 ± 262.9	5.62%	31.1 ± 9.3	7.29 ± 0.41
Decision table	2,992.7 ± 380.5	5.23%	55.2 ± 4.6	7.18 ± 0.42
K*	3,183.5 ± 98.7	5.56%	114.7 ± 1.6	7.63 ± 0.17
KNN, N=85	**3,608.0 ± 394.8**	**6.30%**	38.7 ± 4.9	**6.92 ± 0.19**
JRip	3,153.1 ± 351.8	5.51%	61.4 ± 8.8	7.27 ± 0.47

Table 7: Segregated stacking strategy.

Dwell time Segregated Stacking Strategy

INPUT: Dwell time predictions for each container and dwell time classes; Yard layout and inventory

1. Define the segregation of containers based on the dwell time class predictions
2. Assign to each block a segregation of containers. One block can contain either a single or several segregations.
3. Once a container arrives, assign it to the corresponding segregation block.
4. Define the location of the container in the block based on the ***Semi-random*** or ***Sequential*** stacking strategies.
5. If a container arrives and there is no available space in the block corresponding to the segregation, then randomly select a block and repeat step 4.

OUTPUT: container location.

Table 8: Non-segregated stacking strategy.

Non-Segregated General Stacking Strategy
INPUT: Yard layout and inventory 1. Randomly select a block with available space. 2. Define the location of the container in the block based on the ***Semi-Random*** or ***Sequential*** stacking strategies. 3. If a container arrives and there is no available space in the predetermined block, then randomly select a block and repeat step 4. **OUTPUT:** container location.

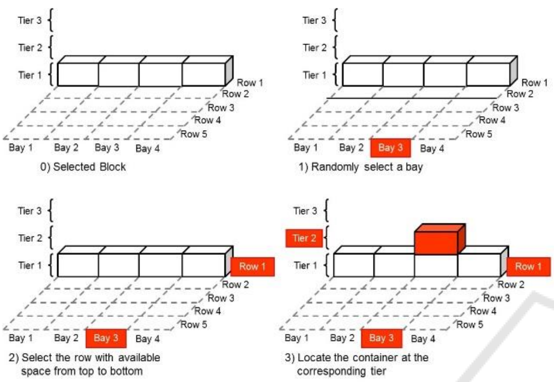

Figure 3: Semi-random stacking strategy illustration.

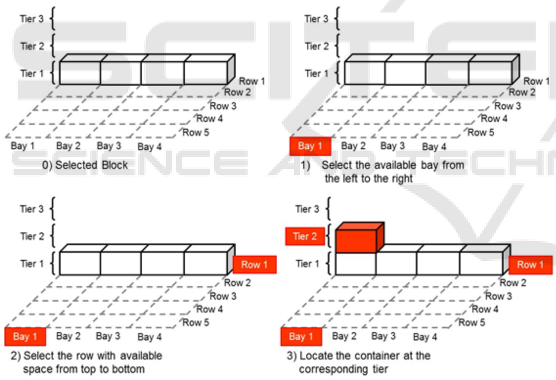

Figure 4: Sequential stacking strategy illustration.

6 CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

Ship turnaround times are an important productivity indicator for a port terminal. Efficient container handling is needed during the loading and unloading operations. Among several factors that affect the performance of the ship service, the yard operation efficiency is a key element. In addition, for those terminals in which land is very restricted, the planning and scheduling of resources at the yard (space and equipment) are even more critical.

A common practice among yard managers for storage space assignment consists of defining segregations or groups of containers with common characteristics. Export container segregations depend on the vessel´s loading sequence, which is based on the vessel´s route, weight and characteristics of the container, among other factors. On the other hand, segregating import containers is more complex. This is more difficult if the port terminal has no hinterland coordination mechanisms and high levels of uncertainty on the times when import container will be requested.

In this article a dwell time segregated storage space policy for import containers is proposed. In addition, the design of a decision support system for the yard planner based on the proposed storage policy is proposed. The focus of this article was import containers, due to the difficulty to determine the criteria to segregate them. As pointed out before, this relies on the high levels of uncertainty on the dispatching times, and the fact that an important number of rehandles are incurred during this process.

For the proposed policy, dwell times of import containers are predicted by classification algorithms. Then, containers are segregated based on dwell time classes. Import containers of the same dwell time class are assigned to close locations at the yard.

As a case study, we consider the particular case of the port of Arica in Chile. This port presents special conditions for cargo handling. More than 70% of the cargo transferred by the port of Arica corresponds to transit cargo of Bolivia. Due to the political agreements maintained between Chile and Bolivia, there exists a high uncertainty in the dispatching processes of the import containers at the port. In order to evaluate the potential benefits in the daily operations of the yard, a discrete event simulation model is also implemented. Numerical results of the simulation model show that a dwell time segregated storage policy with a sequential stacking strategy provides a significant reduction in the number of rehandles incurred. Considering the real number of containers handled by the port for a specific instance data set, around to 17% reduction in rehandles is obtained by the proposed policy. Finally, it is worthy to mention that the implementation of the decision support system proposed may provide a valuable tool for the yard planner.

Table 9: Numerical Results: Rehandles per time period and stacking strategy.

Storage Policy	Stacking Strategy	Average per policy (DT vs NS)	Rehandles per period	
			2012	2013
Non-segregated policy (NS)	Non-segregated random stacking strategy	45840.6	48611.8	43083.6
	Non-segregated sequential stacking strategy		48756	42911
Dwell time segregation policy (DT)	Dwell time segregated and random stacking strategy (JRip)	39768.76	45785.8	37423.8
	Dwell time segregated and sequential stacking strategy (JRip)		45343	36531
	Dwell time segregated and radom stacking strategy (multi-classifier and KNN, *N*=84)		46377.4	27909
	Dwell time segregated and sequential stacking strategy (multi-classifier and KNN, *N*=84)		**45337**	**26986**
Gap (Avg NS - Avg DT)/Avg DT				13.25%
Gap (Best NS - Best DT) /Best DT [2012]				6.74%
Gap (Best NS - Best DT) /Best DT [2013]				37.11%

Current practices of the managers follow a semi-random assignment of containers at the yard, given the limitations of data and uncertainty in the dispatching times of import containers. Hence, the proposed support system will not change significantly their current operations but in turns, will provide recommendations to the yard planners for the assignment of spaces to containers, without replacing the personnel.

As further research additional factors that may affect dwell time predictions should be analyzed, such as the cargo transported in the container. For instance, we could differentiate containers with cargo of a single or several consignees.

The problem addressed in this article is at the tactical decision level. Hence, another research avenue would be to develop real time stacking strategies based on the dwell time segregated policy. Furthermore, impact assessment for different types of yard equipment could be another research project to be developed (reachstackers vs RTG vs straddle-carriers, etc.). Finally, ship turnaround times can be also considered as a performance metric for the different stacking strategies and a sensitivity analysis to determine the most significant factors determining dwell times for the port of Arica is another research avenue.

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