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Optimization of Intermodal Rail-Road Freight Transport Terminals

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Abstract — **In this paper we present a decision support scheme to help managing and optimizing two critical activities in intermodal terminals, namely the containers allocation in the terminal yard and the freight trains composition. In particular, the focus of this paper is on the first problem and the goal is that of maximizing the utilization of the available space while keeping into account several constraints. The approach was successfully tested on a real case study, the rail-road terminal of a leading intermodal logistics company.**

I. Introduction

Nowadays globalization, high productivity and rapid market changes require the standardization of the business processes in order to ensure added values for the whole supply chain [11]. An important link in the supply chain to allow efficiency, speed, reliability and environmental sustainability is represented by transportation. Recently, the transport market is moving towards intermodality and the standardized management of its operational processes and business flows has a high strategic value [5]. One of the key issues in the competitiveness of intermodal transport is the site (terminal) where the modal transshipping takes place. However, the configuration and the optimal control of an intermodal terminal is a very complex and challenging issue.

In the existing optimization models for intermodal terminals, mathematical programming models are effective in representing the terminals characteristics and limitations. However, the relevant literature presents only few works aiming at optimizing inland (rail-road) terminals, with most contributions concerning seaport terminals and their peculiarities. Moreover, the few existing studies often disregard some operational aspects and practical issues, such as some containers characteristics, hence resulting of limited value for real applications. This paper aims to fill the gap by presenting a decision support scheme for the automation of intermodal freight transport companies, with regard to two of the main critical aspects: the yard management and the train load planning. This paper provides a solution to the first problem based on linear integer programming, and allows maximizing the utilization of the available space, keeping into account a series of constraints. A solution to the second problem, still based on linear integer programming, has been recently proposed by some of the authors in [13].

The proposed approach was successfully tested on a real rail-road terminal of an Italian company operating in the intermodal transport in Europe, resulting in a useful tool to enhance the standardization of decisions, thanks to the integration with the enterprise software.

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II. Review on Intermodal Transport Optimization

Since the emergence of intermodal transport, researchers have focused on analyzing, quantifying and valuing possible improvements in the freight transport [8, 25].

Referring to the problem of storage space allocation, it can be treated as a cutting and packing problem [14], or as a knapsack container loading problem [4] aiming at maximizing the filling of a virtual knapsack. However, in these cases some relevant constraints such as the orientation of the container, their weight or their stackability are usually neglected. In the related literature, strategies for locating containers in the yard have been discussed for different cases, mainly depending on the type of containers. In particular, import containers (those that arrive and, after having been stored for a particular time period until departure, are transferred to some other modality at the hinterland of the terminal) are studied in [19], presenting a method for determining both the optimal amount of storage space and the optimal number of yard cranes for handling these containers. Export containers (those that arrive at the terminal via other modes of transportation and, after staying at the yard, leave by ship) are addressed in [20, 21]. An approach covering both cases is proposed in [26], using a rolling horizon approach.

A further classification of intermodal terminal optimization is based on the adopted approach and distinguishes among simulation, expert systems and analytic methods. Referring to the former class, in [15] a simulation model is developed to analyze the transshipment in a terminal, while in [23] a discrete event simulation model is proposed for minimizing the transshipment time of containers from trains placed on parallel tracks with a gantry crane, but without considering the limitations of platforms in the containers loading. In the context of expert systems, in [1] an expert system is developed for evaluating technological innovations in intermodal terminals. In [16] the authors propose a system based on the knowledge for approaching the programming of the vehicle load to be transported by train. In [3] an expert system is adopted combined with a simulation model to analyze a rail-road terminal with advanced equipments. Moreover, [22] proposes a genetic algorithm to determine the optimal storage strategy for various container handling schedules and in [9] the authors present a tabu search algorithm for the storage space allocation with side constraints. As regards analytic methods,

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in [3] a model for approaching loading, unloading and storage of cranes in sea-road terminals is presented. In [24] the authors consider the management of a terminal used for the transshipment of vehicles by adopting analytic methods, but the obtained model is very complex, hence it is divided into sub-models and heuristics solutions are determined. In [6] and [18] the activities of containers managing, storing and handling in a terminal are approached, but both works disregard weight and dimension that have to characterize containers on each platform to allow an appropriate load. In [10] a load planning model is developed to dynamically assign containers to train slots at an intermodal terminal, with the objective to minimize handling time and optimize the mass distribution of the train, but by the simplifying assumption that all containers have the same length. However, in real cases differences and limitations in freight length, weight, balance or arrangement has to be addressed so that containers are correctly placed on wagons.

Among the analytical models for intermodal terminals optimization, mathematical programming models may be effective in including real characteristics and limitations. However, despite the accepted prominence in terms of sustainability of rail transports with respect to other modes [12], most of the existing literature refers to seaport terminals. On the contrary, inland container terminals (i.e., without vessels or ships) is an important issue, as it combines the advantages of rail for long distance transportation with the higher penetration within the territory offered by road [6].

As concerns the rail transport optimization in intermodal terminals, in [7] the containers loading on trains are scheduled by means of a mixed integer linear programming model and with the aim of maximizing the allocation of containers to wagons and minimizing the overall transport costs within the terminal. In this model, for the first time, the weight characteristics of containers are taken into account. More recently, containers have been characterized, as well as by weight, also by their length and commercial value [2]. However, in rail-road terminals the minimization of the internal transport costs seems to be unnecessary, since costs associated with the traveled distances are not distinctive, but they are rather related to seaport terminals, where dimensions are much bigger. In addition, the model in [2] does not consider some relevant aspects, such as the presence of any kind of stringency in the containers delivery or the presence of some priority customer. Moreover, this model does not allow taking into account the train loading/unloading activities in the destination terminal, where containers may be relocated on a new train leaving for a subsequent destination.

In the described context, inland intermodal terminal operators may require a decision support system that is suited to the real characteristics of the terminal in order to better manage both the critical phases of the container placement in the yard and the train load planning.

In the following section we present a decision support scheme in which the optimization of the containers storage in the yard is obtained starting from the basic idea in [14] by adding the existing constraints on weight and stackability, while the train load model presented in [13] is developed from the one in [2] and improved for use in real cases.

III. THE DECISION SUPPORT SCHEME

In this paper we consider a rail-road terminal where containers continuously arrive and should either be immediately loaded on a train directed to a well precise destination, or temporarily stored in the terminal yard, before being loaded on a train. Our goal is twofold: first, we want to determine optimal compositions of trains; second, we want to optimize the storage of containers in the yard. A series of properties are associated with each container: destination, delivery date, and commercial value. When computing the train composition we try to ensure the greatest profit while respecting the existing constraints on containers and wagons size, containers weight, wagons capacity, containers type (rigid, tank or soft top), filling level (full or empty), the presence of any kind of stringency in the containers delivery, the presence of some priority customer for the company, so as to weigh the commercial value of the container by the impact on the overall value of the train composition.

The proposed optimization is performed both at a local terminal level and at a global transport supply chain level. Moreover, either in case of subsequent changes (e.g., for a new stringency) or in case of loaded containers that are initially loaded but afterwards discarded (e.g., for safety reasons, due to the low computational time of the model) the optimization can be easily performed again, hence allowing a simple management of this phase. A train load planning optimization technique is proposed in [13].

Containers that are not immediately departing or have not been loaded on the train due to overbooking must be stored in the yard. This is done with the objective of maximizing the filling level of the available space in the yard while respecting any existing physical constraints on size, weight and stacking, which vary according to the type of container. Further, it is desirable that, if the stacking is feasible, containers with a farther departure date are placed below those departing before. The model also allows deciding whether to replace stored containers, e.g., as their delivery date is forthcoming, so as to avoid that they are placed below others. To simplify the subsequent trains' composition, the yard is assumed to be divided into different zones, each of predetermined dimensions, according to the different target locations. In this way each area is designed to receive only containers to be loaded on the same train, ensuring transit routes to forklifts in the yard. Consequently, it is necessary to apply the model to each zone in which the yard is divided.

In this paper we propose the decision support scheme in Fig. 1 that allows to jointly and recursively solve the above two optimization problems: the yard management and the train load planning.

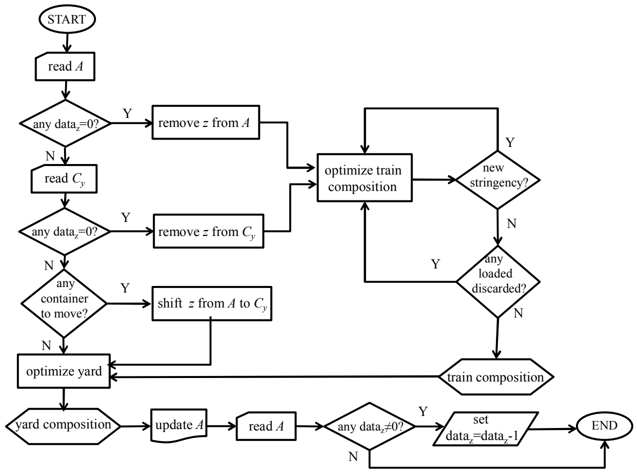

Figure 1. The proposed decision support system.

The decision support scheme is based on the assumption that the company database associates a flag $data_z$ to the generic container z with a given destination. The flag $data_z$ may take values in the set of natural numbers since no more than one train a day leaves for a given destination: if at a certain day it is $data_z$=0 then the container z belongs to the list of containers departing in that day, if $data_z=q$ then the container belongs to the list of containers leaving after q days. The list of containers with $data_z$=0 provides the input to the train composition problem. The output of such an optimization problem consists in the list of containers actually scheduled to be loaded on the considered train and their positions on the train wagons. According to the notation of Fig. 1, A is the list of flags associated with containers in the yard, while C_y is the list of flags associated with incoming containers. As shown in Fig. 1, only trains with $data_z$=0 are considered in the step denoted as "optimize train composition". Before solving the optimization problem, the presence of "new stringencies" is verified. If any, the optimization problem is updated accordingly. Note that the optimization also needs to be repeated when for any reason some container needs to be discarded. In Fig. 1 this case corresponds to a positive answer to the query "any loaded discarded?". In the absence of new stringencies and discarded containers, the train composition is finally computed. On the other hand, all incoming containers such that $data_z \neq 0$ are moved to the yard (see step "shift z from A to C_y" in Fig. 1). The list of containers to be stored in the yard, that also includes the containers that are not loaded on the train even if $data_z$=0, provides the input to the problem "optimize yard" that enables to obtain the yard composition. After that, the set A is updated accordingly. Note that also flags $data_z$ need to be updated: in particular, flags associated with containers that were already considered in the train composition problem but have not been loaded on the train, keep their flag equal to 0, the other containers reduce their flag of one unit since the number of days before their departure decreases of one unit.

IV. Storage Optimization of Containers in the Terminal Yard

In this section we discuss how it is possible to solve the problem of optimally storing containers in the terminal yard by a linear integer programming problem. The aim is to maximize the filling level of the available space while respecting the physical constraints on size and stacking (based on containers weight), which vary according to the type of container. Furthermore, it is desirable that, if the stacking is feasible, containers with a farther departure date are placed below those departing before. As seen above, to simplify the management of the departing trains composition, we assume that the yard is divided into different zones according to the target locations, and each area is divided into 5 feet slots. Moreover, for safety reasons no more than 4 containers can be stacked. Therefore, each area is rounded up to an integer number of available positions a, b and c.

In the rest of the paper we use the following notation:

- C_y is the ordered set of n' indices of incoming containers to be placed in the yard and having the same destination;
- A is the ordered set of m' indices of containers already stored in the considered area with the same destination of C_y;
- $z \in C_y \cup A$ is the integer index identifying the generic arriving container to be placed in the considered area or already stocked in that area;
- $l_z \in \{20, 30, 45\}$ is the length, measured in feet, of the z-th container;
- $k_z \in \{0,1\}$ is a binary variable indicating the kind of the z-th container, equal to 1 if it is a rigid one or a tank, 0 otherwise;
- $f_z \in \{0,1\}$ is the binary variable indicating whether the z-th container is full (equal to 1) or empty (0);
- $P \in \{1,2,...,a\} \times \{1,2,...,b\} \times \{1,2,...,c\}$ is the set of available positions in the considered area of the yard;
- $i \in \{1,2,...,a\}$, $j \in \{1,2,...,b\}$ and $k \in \{1,2,...,c\}$ are indices referred to the position (respectively for length, depth, and height) in the considered area;
- $SF = \{z \in C_y \cup A \mid k_z = 0 \wedge f_z = 1\}$ is the set of indices of soft top and full containers to be placed (or already stocked) in the considered area;
- $SE = \{z \in C_y \cup A \mid k_z = 0 \wedge f_z = 0\}$ is the set of indices of soft top and empty containers;
- $RF = \{z \in C_y \cup A \mid k_z = 1 \wedge f_z = 1\}$ is the set of indices of rigid and full containers;
- $RE = \{z \in C_y \cup A \mid k_z = 1 \wedge f_z = 0\}$ is the set of indices of rigid and empty containers;

- $Z_{20} = \{ z \in C_y \cup A \mid l_z = 20 \}$ is the set of indices of 20 feet long containers (occupying 4 slots in length) to be placed (or already stocked) in the considered area;

- $Z_{30} = \{ z \in C_y \cup A \mid l_z = 30 \}$ is the set of indices of 30 feet long containers (occupying 6 slots in length);

- $Z_{45} = \{ z \in C_y \cup A \mid l_z = 45 \}$ is the set of indices of 45 feet long containers (occupying 9 slots in length);

- $x_{z,i,j,k} \in \{0,1\}$ is the binary decision variable indicating whether the z-th container is assigned to position $p_{i,j,k}$ (value 1) or not (value 0). Note that, if the position $p_{i,j,k}$ is already occupied by a previously positioned container, then it may be imposed $x_{z,i,j,k} = 1$ at that position, since usually it is not economically convenient to shift an already positioned container. However, the decision maker may also wish to shift some of these containers, e.g., because their shipping date is upcoming and thus it is not beneficial to stack other containers on them. In such cases, by simply interfacing the model with the company software, it becomes very easy for the end user to reload the simulation also considering these containers and by treating them as if they have just been delivered in the yard.

Hence, the following optimization problem can be written:

$$\max F = \sum_{z \in C_y \cup A} \sum_{i \in \{1,2,\ldots,a\}} \sum_{j \in \{1,2,\ldots,b\}} \sum_{k \in \{1,2,\ldots,c\}} x_{z,i,j,k} \quad (1)$$

subject to:

$$x_{z,i,j,k} + x_{z,i+1,j,k} + x_{z,i+2,j,k} + x_{z,i+3,j,k} = 4 \ \forall z \in Z_{20} \quad (2.1)$$

$$\begin{aligned} & x_{z,i,j,k} + x_{z,i+1,j,k} + x_{z,i+2,j,k} + x_{z,i+3,j,k} + \\ & \quad + x_{z,i+4,j,k} + x_{z,i+5,j,k} = 6 \ \forall z \in Z_{30} \end{aligned} \quad (2.2)$$

$$\begin{aligned} & x_{z,i,j,k} + x_{z,i+1,j,k} + x_{z,i+2,j,k} + x_{z,i+3,j,k} + \\ & \quad + x_{z,i+4,j,k} + x_{z,i+5,j,k} + x_{z,i+6,j,k} + x_{z,i+7,j,k} + \\ & \quad + x_{z,i+8,j,k} = 9 \ \forall z \in Z_{45} \end{aligned} \quad (2.3)$$

$$\sum_{z \in C_y \cup A} x_{z,i,j,k} \le 1 \quad \forall i,j,k \quad (3)$$

$$\sum_{z \in C_y \cup A} \sum_{i \in \{1,2,\ldots,a\}} x_{z,i,j,k} \le a \quad \forall j,k \quad (4)$$

$$\sum_{z \in C_y \cup A} \sum_{j \in \{1,2,\ldots,b\}} x_{z,i,j,k} \le b \quad \forall i,k \quad (5)$$

$$\sum_{z \in RF \cap Z_{20}} \sum_{k \in \{1,2,\ldots,c\}} x_{z,i,j,k} \le 3 \quad \forall i,j \quad (6.1)$$

$$\sum_{z \in RF \cap Z_{30}} \sum_{k \in \{1,2,\ldots,c\}} x_{z,i,j,k} \le 3 \quad \forall i,j \quad (6.2)$$

$$\sum_{z \in RF \cap Z_{45}} \sum_{k \in \{1,2,\ldots,c\}} x_{z,i,j,k} \le 3 \quad \forall i,j \quad (6.3)$$

$$\sum_{z \in RF \cap Z_{20}} \sum_{k \in \{1,2,\ldots,c\}} x_{z,i,j,k} \le 1 \quad \forall i,j \quad (7.1)$$

$$\sum_{z \in SF \cap Z_{30}} \sum_{k \in \{1,2,\ldots,c\}} x_{z,i,j,k} \le 1 \quad \forall i,j \quad (7.2)$$

$$\sum_{z \in SF \cap Z_{45}} \sum_{k \in \{1,2,\ldots,c\}} x_{z,i,j,k} \le 1 \quad \forall i,j \quad (7.3)$$

$$\sum_{z \in SE \cap Z_{20}} \sum_{k \in \{1,2,\ldots,c\}} x_{z,i,j,k} \le 3 \quad \forall i,j \quad (8.1)$$

$$\sum_{z \in SE \cap Z_{30}} \sum_{k \in \{1,2,\ldots,c\}} x_{z,i,j,k} \le 3 \quad \forall i,j \quad (8.2)$$

$$\sum_{z \in SE \cap Z_{45}} \sum_{k \in \{1,2,\ldots,c\}} x_{z,i,j,k} \le 3 \quad \forall i,j \quad (8.3)$$

$$\sum_{z \in RE \cap Z_{20}} \sum_{k \in \{1,2,\ldots,c\}} x_{z,i,j,k} \le 4 \quad \forall i,j \quad (9.1)$$

$$\sum_{z \in RE \cap Z_{30}} \sum_{k \in \{1,2,\ldots,c\}} x_{z,i,j,k} \le 4 \quad \forall i,j \quad (9.2)$$

$$\sum_{z \in RE \cap Z_{45}} \sum_{k \in \{1,2,\ldots,c\}} x_{z,i,j,k} \le 4 \quad \forall i,j \quad (9.3)$$

The objective function allows maximizing the filling level of the available space in compliance with a set of constraints.

Constraint (2.1) takes into account that each 20 feet container cannot be divided, and therefore occupies 4 slots that are necessarily adjacent (according to index i, so as to facilitate the subsequent load on the train, since this dimension is the one parallel to the rail tracks). Likewise for 30 and 45 feet containers constraints (2.2) and (2.3) arise.

Constraint (3) requires that to each position $p_{i,j,k}$ no more than one container can be assigned.

Constraint (4) requires that, for any value of j and k, the maximum number of occupied slots along i is equal to a.

Similarly to the previous one, constraint (5) specifies that, for any value of i and k, the maximum number of occupied slots along j is equal to b.

Constraint (6.1) requires that, for any value of i and j, the maximum number of rigid and full 20 feet containers along k is set to 3, for safety reasons in stacking, regardless of c. The same constraint applies also for rigid and full containers of other dimensions: see constraints (6.2) and (6.3).

Constraint (7.1) requires that for any value of i and j, the maximum number of soft top and full 20 feet containers along k is 1, for safety reasons in stacking. Similarly, for soft top and full containers of other dimensions, (7.2) and (7.3) arise.

Constraint (8.1) states that for any i and j, the maximum number of soft top and empty 20 feet containers along k is 3, for safety reasons. Similarly, for soft top and empty containers of other dimensions constraints (8.2) and (8.3) arise.

Finally, constraint (9.1) requires that, for any value of i and j, the maximum number of rigid and empty 20 feet container along k is set to 4, and similarly for containers of the same kind but with other dimensions constraints (9.2) and (9.3) arise.

The above optimization problem has a number of binary unknowns equal to $(|C_y|+|A|)\cdot a\cdot b\cdot c$ and a number of constraints equal to $(1+|Z_{20}|+|Z_{30}|+|Z_{45}|+a\cdot b\cdot c+b\cdot c+a\cdot c+12a\cdot b)$.

V. CASE STUDY

The performance of the proposed model is evaluated by a real case study in the terminal located in Bari (Southern Italy) at "GTS - General Transport Service S.p.A.", a leader in intermodal freight transport in Italy and Europe, owning about 1.800 containers of different types and 280 train wagons. The critical issues for the company are the lack of standardization in positioning containers in the yard and the lack of optimization criteria in the trains composition, as well as the lack of computerized tools enabling to have constantly updated reports on the large existing information and freight flows. Currently, both the container allocation in the yard and the train composition are manually decided by the corresponding operator, based on his personal experience and considering the physical constraints and factors such as the customer importance and reliability, the freight characteristics and the presence of fixed delivery dates or other contractual obligations.

In order to facilitate their use by the employees, both the approach in the above section and the train composition approach in [13] have been implemented in the company software, which is based on MS Visual Studio, interfacing them with the business database by means of MS Excel spreadsheets.

The first step of the proposed technique is to identify the best allocation for containers in the yard, so as to maximize its filling level in compliance with the existing constraints. Tables I and II respectively report the sets of containers to be placed in the yard (C_y) and of those already stored (A), while Fig. 2 graphically depicts the starting situation of the area, reporting at each level the slots in which it is divided.

TABLE I. CONTAINER TO BE PLACED IN THE CONSIDERED AREA (C_Y).

z	l_z	k_z	f_z	$data_z$	z	l_z	k_z	f_z	$data_z$
101	20	0	0	1	117	45	0	1	1
102	20	0	1	2	118	45	0	0	2
103	20	0	1	2	119	45	0	0	1
104	20	0	1	2	120	45	1	0	1
105	20	0	1	1	121	45	0	1	0
106	20	0	1	1	122	45	0	1	0
107	30	0	1	2	123	45	0	1	0
108	30	0	1	1	124	45	0	1	0
109	30	1	1	1	125	45	0	1	0
110	45	0	1	2	126	45	1	1	0
111	45	0	1	2	127	45	1	1	0
112	45	0	1	1	128	20	0	1	0
113	45	0	1	1	129	45	0	1	0
114	45	0	0	1	130	45	0	1	0
115	45	0	1	2	131	45	0	1	0
116	45	0	1	1	132	45	1	1	0

TABLE II. CONTAINERS ALREADY STOCKED IN THE AREA (A).

z	l_z	k_z	f_z	$data_z$	$p_{j,i,k}$	z	l_z	k_z	f_z	$data_z$	$p_{j,i,k}$
1	20	0	0	0	(1,1,1)	22	45	0	0	1	(5,9,1)
2	20	0	0	1	(2,1,1)	23	45	1	1	1	(6,9,1)
3	20	0	0	0	(3,1,1)	24	45	0	1	0	(2,9,1)
4	20	0	1	1	(1,5,1)	25	45	0	0	0	(3,9,1)
5	20	0	1	1	(2,5,1)	26	45	0	0	0	(4,9,1)
6	20	0	1	0	(3,5,1)	27	20	0	0	0	(1,1,2)
7	30	0	1	1	(4,1,1)	28	20	0	0	0	(2,1,2)
8	30	0	1	1	(5,1,1)	29	20	0	1	0	(1,5,2)
9	30	0	1	1	(6,1,1)	30	45	0	0	0	(1,9,2)
10	30	0	1	1	(5,1,2)	31	45	0	1	0	(5,18,2)
11	30	1	1	1	(6,1,2)	32	45	1	1	0	(5,9,2)
12	45	0	1	1	(1,18,1)	33	30	0	1	0	(4,1,2)
13	45	0	1	1	(2,18,1)	34	45	0	1	0	(3,19,2)
14	45	0	1	1	(3,18,1)	35	20	0	1	0	(2,5,2)
15	45	0	1	1	(1,18,2)	36	45	0	1	0	(2,9,2)
16	45	0	1	0	(2,18,2)	37	45	0	0	0	(3,9,2)
17	45	0	0	1	(1,9,1)	38	45	0	1	0	(1,18,3)
18	45	0	1	1	(4,18,1)	39	20	0	0	0	(1,1,3)
19	45	0	1	1	(5,18,1)	40	20	0	0	0	(2,1,3)
20	45	0	1	1	(6,18,1)	41	20	0	1	0	(1,5,3)
21	45	0	0	0	(6,18,2)	42	30	0	1	0	(5,1,3)

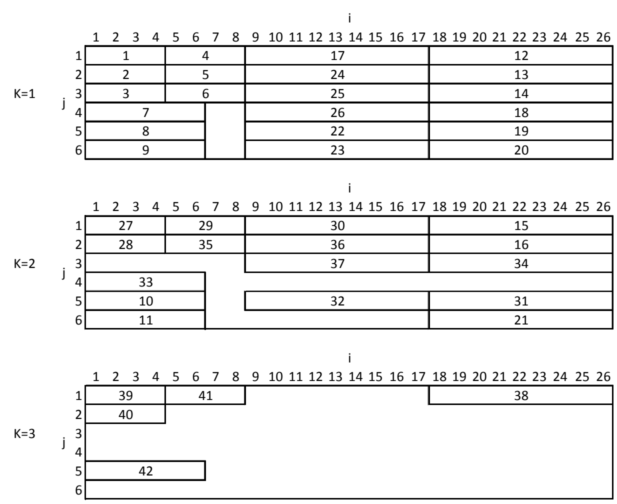

Figure 2. The starting situation at level I (k=1), II (k=2) and III (k=3).

All considered containers have the same destination, and the relative area in the yard has dimensions of approximately 50x130 square feet. On the basis of the foregoing it follows that the available space is for about 6 rows of containers in depth, while there are 24 slots (5 ft each) in length and, as mentioned, no more than 4 containers can never be stacked in height, hence a=24, b=6 and c=4.

The model has been implemented and solved in the MATLAB environment using the GLPK (Gnu Linear Programming Kit) optimizer tool [17]. Fig. 3 shows the obtained output, with a computational time of just about 30 seconds on a Pentium 4 PC with a 1.92 GHz processor and 512 MB of RAM, once the input data were loaded from the company database (it takes few minutes).

From Fig. 3 it can be seen that containers having index z=102 was assigned to the position (1,5,2), i.e. above the one with index z=4, that is one of those of the same size and type, and similarly all containers are located with respect of the imposed constraints. Moreover, in case of more containers that can be placed in the same position, it is sufficient to sort them by departure date in a descending order, to place as first, and hence below the others, those departing later.

The procedure in [13] has been subsequently applied to determine the train composition and the optimal load planning. Results are not reported here for brevity requirements. Once the train composition phase is over, all discarded containers can be placed in the storage area, by rerunning the yard composition model. In this way, these containers, which are characterized by a closer departure date, will be placed on top of the others, making it easier to load them on the next train composition.

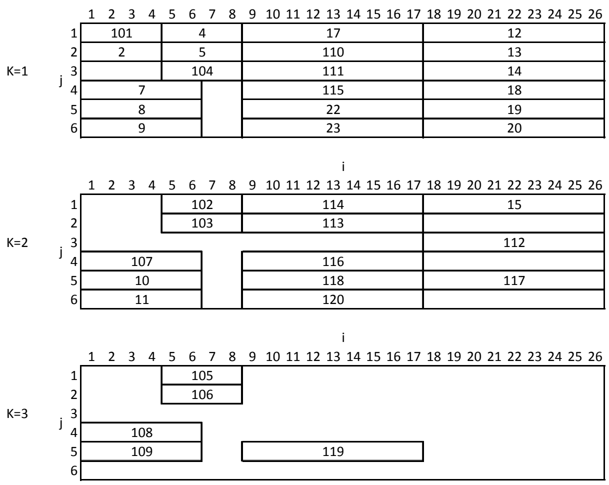

Figure 3. Positioning of containers in the yard area.

Overall, the management of both phases by means of the proposed tool takes approximately 5 minutes, most of which are needed to import the input data from the corporate database. Hence, once data is imported, a new optimization problem (e.g., with different constraints) may be actually solved in less than 1 minute.

VI. Conclusions

We propose a support decision scheme for optimizing two critical issues at intermodal company rail terminals: the allocation of containers in the yard (maximizing the filling level) and the composition of freight trains (maximizing the company profit). We fill the gap found in the related literature that typically considers optimization models for seaport terminals only. We also present an approach based on linear integer programming to solve the yard composition problem, while the train composition and load planning problem is solved using an approach presented by some of the authors in [SMC]. The model has been tested on a real case study and, thanks to the short computational times, it guarantees a high flexibility.

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