Models for Train Load Planning Problems in a Container Terminal

Daniela Ambrosino and Silvia Siri

Abstract In this chapter, the train load planning problem for maritime container terminals is dealt with. In the most general case, the optimal assignment of containers to train slots is done considering that it is possible to make reshuffles in the stacking area and to load the train not sequentially; of course, both these types of unproductive movements should be minimized. In the chapter, a general formulation for this problem is provided, as well as other two formulations for the specific cases in which one of these two unproductive operations is not allowed. Then, some experimental results are reported to show the differences among the proposed models.

Keywords Maritime container terminals · Train load planning · Combinatorial optimization

1 Introduction

Container terminals are very complex systems that require the development of optimization methods to support the crucial decisions at the different planning levels, from the strategic to the tactical until the operational one [1]. Some recent surveys on operations research methods applied to container terminals are those provided by Steenken et al. [2] and Stahlbock and Voss [3]. The authors divide the optimization approaches found in the literature according to the different processes

D. Ambrosino
Department of Economics and Business Studies, University of Genova, Genova, Italy
e-mail: daniela.ambrosino@economia.unige.it

S. Siri (✉)
Department of Informatics, Bioengineering, Robotics and Systems Engineering, University of Genova, Genova, Italy
e-mail: silvia.siri@unige.it

J. F. de Sousa and R. Rossi (eds.), *Computer-based Modelling and Optimization in Transportation*, Advances in Intelligent Systems and Computing 262,
DOI: 10.1007/978-3-319-04630-3_2,

in a seaport terminal: ship planning (i.e. berth allocation, stowage planning and crane split), storage and stacking planning, and transport optimization (divided in quayside, landside, and crane movements). With respect to this classification, the present chapter concerns the landside transport planning and presents an optimization approach for the definition of loading plans for trains.

As highlighted in Steenken et al. [2], a loading plan indicates on which wagon a container must be placed; generally speaking, this decision depends on the container destination, type and weight, as well as on the characteristics of the train and wagons. The container location in the stacking area can influence the loading plan as well. In this chapter, we consider the case in which the loading plan is performed by the terminal operator with the aim of optimizing both the pick-up operations in the stacking area where containers are waiting for being loaded on trains and the loading operations of each train.

In the literature few works are specifically devoted to the train loading problem, as it is in our work. Bostel and Dejax [4] deal with rail–rail terminals with rapid transfer yards and propose some models and heuristic methods for container allocation problems on trains. Corry and Kozan [5] consider a terminal where containers are transferred to and from trucks on a platform adjacent to the rail tracks provided with a short-term storage area. They propose several techniques for defining the assignment of containers to slots of a train, minimizing container handling time and optimizing the weight distribution of the train. In that model, only one type of container is considered and the weight restrictions for the wagons are neglected. In a following work, Corry and Kozan [6] treat again the train planning problem, considering more types of containers and different loading patterns and minimizing a weighted sum of number of wagons required and equipment working time. Due to the large number of variables, they propose heuristic algorithms, such as local search and simulated annealing, to solve the problem in practical applications. The load planning problem in intermodal terminals is also studied by Bruns and Knust [7] that consider explicitly the real weight constraints for wagons, as we do in this chapter. They propose three different integer linear programming formulations for solving the problem of loading containers on wagons in order to maximize the utilization of the train and minimize transportation costs for loading containers and set up costs for changing the configuration of wagons. Many types of containers are considered (including also swap bodies) and different types of wagons are treated.

In the present chapter, we develop a mathematical model to optimally plan the train load in order to maximize the train utilization, while minimizing the unproductive activities that can arise both in the stacking area and during the train loading operations executed by the crane. Real weight constraints are explicitly considered, as done by Bruns and Knust [7], and the main novelty of the present approach with respect to the one by Bruns and Knust [7] stands in modeling the reshuffles in the stacking area, since this is a crucial aspect to be dealt with in maritime container terminals. The model proposed in this chapter is an extended version of the one developed by Ambrosino et al. [8] where, again, the train load planning problem was treated but only in the case of sequential loading by the crane. A model similar to the one proposed in this chapter has been considered by Ambrosino et al. [9] to evaluate the impact of various storage policies adopted in the yard on different train loading strategies. In this chapter three different models are validated and compared in order to understand which model is the most suitable for solving real problems in maritime container terminals (i.e. providing good and applicable solutions in an acceptable CPU time).

The chapter is organized as follows. Section 2 is devoted to introduce the problem and the main issues related to it. Section 3 reports the mathematical formulation for the planning problem, both in the general case and in the specific cases of train sequential loading and no-reshuffle policy for the stacking area. Section 4 regards the experimental analysis performed on the three different formulations. Finally, some conclusions are drawn in Sect. 5.

2 Problem Description

The problem studied in this chapter regards the train load planning in seaport terminals. The destination of containers is not taken into account in this load planning problem, since the planning is related to the shuttle trains directed to the inland port (for which the inland terminal is the only common destination). Thus it is assumed that the containers in the stacking area have the same destination. Moreover, the planning problem considers only one train at a time. Anyway, the proposed approach can be easily modified in order to face the loading problem when in the stacking area containers of different destinations are stored.

This work takes inspiration from a real case of an Italian port but it can be easily extended to many other cases. This study refers to a container terminal in which containers that will be loaded on trains are stored in a specific stacking area close to the railway yard. From there, containers are moved near the tracks with trailers; then, a crane loads containers on trains. Generally, the crane starts its work from a wagon and goes on along the train without changing direction (i.e. going forward). Sometimes, during the loading process it can happen that it is not possible to load a container on the train without requiring to the crane to change direction; in this case, for example, the crane has to come back to load a container in a slot of a wagon already visited by the crane itself but remained free (in this way, unproductive movements of the crane are executed).

Containers are stored in the stacking area in stacks of different height. During the loading process, it is not always possible to pick up firstly the containers at the top of the stacks. Sometimes it can be necessary to remove a container from the top of a stack for loading, on the wagon served by the crane, another container that is below it (in this case a reshuffle is executed).

Figure 1 reports a simple example of two different ways for loading, on 2 wagons, 4 containers belonging to the same stack. First of all, in t1 (first operation), for loading container c3 in the first slot of wagon 1, container c4 must be rehandled (container c4 is loaded in t2, i.e. as second operation; obviously we are

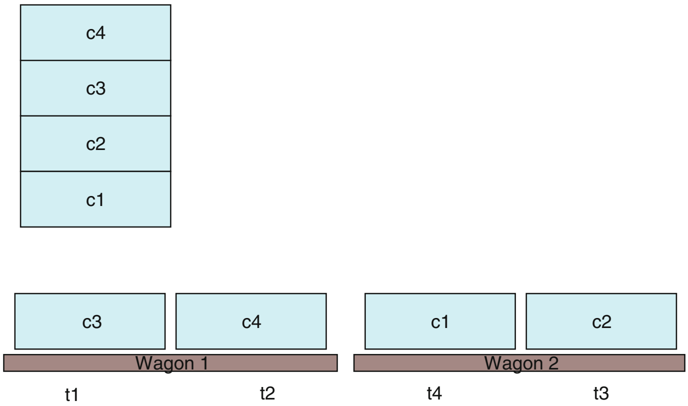

Fig. 1 Sketch of the train loading phase

assuming that c4 cannot be loaded in the first slot e.g. for weight constraints). Then, when loading wagon 2, the crane loads firstly container c2 (third operation) and then goes back for loading container c1; instead of the unproductive crane movement, the same load configuration can be obtained by rehandling container c2 for loading c1 (as happened in wagon 1) and then loading c2.

The assignment of containers to slots is guided by length and weight considerations. One of the characteristics of this problem is the possibility of choosing a particular weight/slot configuration among different ones available for each wagon. These real wagon weight constraints are much stricter than simply considering a maximum weight capacity for each wagon and train. Further details on different wagon configurations can be found in the paper by Bruns and Knust [7] and in the work by Ambrosino et al. [8].

In the problem under investigation the main objective is to plan the train load in order to minimize both the reshuffles in the stacking area and the unproductive movements of the crane loading a train, whilst maximizing the load of the train. As far as the maximization of the load of the train is considered, we have to note that the maximization regards the number of TEUs and the total value of containers loaded instead of the number of containers, since we have to take into account that each container in the stacking area has a different priority to be loaded on a given train. This priority can be directly connected to the due time of the container or to its commercial value.

More formally, given a set of containers with different characteristics (length, weight, and priority) and one train composed by a set of wagons of different types (i.e. with different length, possible configurations and weight constraints), the problem is to choose which containers to load on the train and in which wagon slot. Moreover, the sequence of loading operations must be decided. For this case, a mathematical formulation will be provided. Moreover, other two models can be developed for the specific cases in which either unproductive movements of the crane are not allowed (train sequential loading) or reshuffles are not allowed in the stacking area.

3 Formulation of the Train Load Planning Problem

The mathematical formulation for the train load planning problem is a multi-objective 0/1 Mixed Integer programming model.

3.1 Notation

Let us introduce the notation. First of all, let C denote the number of containers in the stacking area, W the number of wagons of the train to be loaded, S the number of train slots.

For each container $i = 1, \ldots, C$, the weight is denoted as w_i (expressed in tons), the length as λ_i (i.e. 20 or 40 feet), the cost for not being loaded as π_i (it depends on the priority of the container). Moreover, $\gamma_{i,j}, i,j \in \{1, \ldots, C\}, i \neq j$, is related to the position of containers in the stacking area; it is equal to 1 if container i and j are positioned in the same stack and container i is over container j, it is equal to 0 otherwise.

For each wagon $w = 1, \ldots, W, S_\omega$ is the subset of relative slots, B_ω is the subset of weight configurations, ϖ_ω is the weight capacity. Moreover, $B_{s,\omega}$ is the subset of weight configurations for slot s of wagon ω, μ_s is the length of slot s (i.e. 20 or 40 feet), ρ_s is the position of slot s in the train with respect to the first slot of the first wagon (expressed in TEUs), $\delta_{b,s}$ is the weight capacity of slot s in the weight configuration b, $\overline{\Omega}$ is the weight capacity of the train.

Finally, some configuration parameters are the unitary rehandling cost α, the unitary crane movement cost β and the maximum number of possible loading operations on the train T, that corresponds to the TEU capacity of the train.

3.2 General Formulation

In this section let us firstly consider the case in which both reshuffles in the stacking area and unproductive crane movements can be executed. The problem decision variables can be divided in the following sets:

- $x_{i,s,t} \in \{0, 1\}, i = 1, \ldots, C, s = 1, \ldots, S, t = 1, \ldots, T$, equal to 1 if container i is loaded in slot s at operation t, 0 otherwise (these variables are defined only when container i is compatible with slot s in terms of length, i.e. $\lambda_i = \mu_s$);
- $f_{\omega,b} \in \{0, 1\}, \omega = 1, \ldots, W, b \in B_\omega$, equal to 1 if configuration b is chosen for wagon ω, 0 otherwise;
- $y_{i,j} \in \{0, 1\}, i,j \in \{1, \ldots, C\} : \gamma_{i,j} = 1$, equal to 1 if container i is handled to load container j;

- $z_t \geq 0, t = 2, \ldots, T$, unproductive distance traveled by the crane when doing operation t (to compute this variable, it is assumed that the crane is positioned at the beginning over the first wagon on the left and z_t is equal to 0 if the crane, between $t-1$ and t, goes straight, from left to right, whereas it is equal to the covered distance (in TEUs) if the crane goes back, i.e. from right to left);
- $u_t \geq 0, t = 2, \ldots, T$, normally set to 0 except for the operation t such that $t-1$ is the last loading operation by the crane; in that case u_t is positive in order to set $z_t = 0$.

The general formulation is provided in the following:

$$\min \alpha \cdot \sum_{\substack{i,j \in \{1,\ldots,C\}: \\ \gamma_{i,j}=1}} y_{i,j} + \beta \cdot \sum_{t=2}^{T} z_t + \sum_{i=1}^{C} \pi_i \cdot \left(1 - \sum_{s=1}^{S}\sum_{t=1}^{T} x_{i,s,t}\right) \tag{1}$$

$$\text{s.t.} \sum_{s=1}^{S}\sum_{t=1}^{T} x_{i,s,t} \leq 1 \quad i = 1, \ldots, C \tag{2}$$

$$\sum_{i=1}^{C}\sum_{s=1}^{S} x_{i,s,t} \leq 1 \qquad t = 1, \ldots, T \tag{3}$$

$$\sum_{i=1}^{C}\sum_{t=1}^{T} x_{i,s,t} \leq 1 \quad s = 1, \ldots, S \tag{4}$$

$$\sum_{b \in B_\omega} f_{w,b} = 1 \quad \omega = 1, \ldots, W \tag{5}$$

$$\sum_{i=1}^{C}\sum_{t=1}^{T} w_i \cdot x_{i,s,t} \leq \sum_{b \in B_{s,\omega}} \delta_{b,s} \cdot f_{\omega,b} \quad \omega = 1, \ldots, W \quad s \in S_\omega \tag{6}$$

$$\sum_{i=1}^{C}\sum_{s \in S_\omega}\sum_{t=1}^{T} w_i \cdot x_{i,s,t} \leq \varpi_\omega \quad \omega = 1, \ldots, W \tag{7}$$

$$\sum_{i=1}^{C}\sum_{s=1}^{S}\sum_{t=1}^{T} w_i \cdot x_{i,s,t} \leq \overline{\Omega} \tag{8}$$

$$\sum_{s=1}^{S}\sum_{t=1}^{T} t \cdot x_{i,s,t} - \sum_{s=1}^{S}\sum_{t=1}^{T} t \cdot x_{j,s,t} \leq T \cdot y_{i,j} + T\left(\sum_{s=1}^{S}\sum_{t=1}^{T} x_{i,s,t} - \sum_{s=1}^{S}\sum_{t=1}^{T} x_{j,s,t}\right) \quad i,j \in \{1,\ldots C\} : \gamma_{i,j} = 1 \tag{9}$$

$$z_t \geq \sum_{i=1}^{C}\sum_{s=1}^{S} \rho_s \cdot x_{i,s,t-1} - \sum_{i=1}^{C}\sum_{s=1}^{S} \rho_s \cdot x_{i,s,t} - u_t \qquad t = 2, \ldots, T \tag{10}$$

$$u_t \leq T\left(\sum_{i=1}^{C}\sum_{s=1}^{S} x_{i,s,t-1} - \sum_{i=1}^{C}\sum_{s=1}^{S} x_{i,s,t}\right) \quad t = 2,\ldots,T \tag{11}$$

The objective function (1) minimizes a weighted sum of different cost terms, corresponding to the rehandling cost in the stacking area, the unproductive crane movements, and a penalty paid for containers not loaded on the train. The penalty is higher for containers having a high commercial value (priority).

The first three sets of constraints regard the assignment of containers to train slots: each container can be assigned at most to one slot (2); at most one container-slot assignment is done for each operation (3); and, in each slot, at most one container can be loaded (4). Other constraints regard the weight restrictions. First of all, for each wagon, a given weight configuration must be chosen (5). Moreover, (6), (7) and (8) represent the weight capacity constraints for each slot, each wagon and for the whole train. Constraints (9) ensure that the rehandling variables $y_{i,j}$ are correctly computed; in particular, it is important to remember that container i is rehandled if, when operation t is executed, a container j that is located in the stacking area under i is loaded and container i has not yet been loaded on the train. Finally, constraints (10)–(11) ensure that variables z_t and u_t are correctly computed.

This formulation differs from the one proposed by Ambrosino et al. [9] where the initial position of the crane is not fixed and in the objective function the total distance traveled by the crane is minimized; hence constraints (10) and (11) are different, and in model (1)–(11) variables z_t assume positive values only when the crane goes back to an already visited slot. Moreover, also a different formulation for computing reshuffles is used (i.e. constraints (9) are different in number and size).

3.3 Formulation for the Cases Without Unproductive Crane Movements or Without Reshuffles

In the general formulation (1)–(11), by properly tuning parameters α and β, it is possible to consider a train loading process in which the unproductive crane movements and the reshuffles are weighted in different ways. Hence, by associating a very high value to one of these two parameters, it is possible to represent the specific cases without unproductive crane movements or without reshuffles. However, from the experimental campaign performed, we have realized that it is better (from a computational point of view) to define specific formulations for these particular problems. For the sake of brevity, in the following, these models will be described without reporting the complete formulation, that is straightforward.

As regards the case of train sequential loading (i.e. no unproductive crane movements are allowed), the decision variables to be considered are the following. First of all, the assignment variables are no more indexed with t since, in the case of sequential loading, the order of loading operations is given by the position of the slot where a container is loaded. Then, these variables are $x_{i,s} \in \{0, 1\}, i = 1, \ldots, C, s = 1, \ldots, S$, equal to 1 if container i is loaded in slot s, 0 otherwise (again, these variables are defined when $\lambda_i = \mu_s$). Variables $f_{\omega,b} \in \{0, 1\}, \omega = 1, \ldots, W, b \in B_\omega$ and $y_{i,j} \in \{0, 1\}, i, j \in \{1, \ldots, C\} : \gamma_{i,j} = 1$, are defined exactly as in the general formulation. Then, cost function (1) is rewritten without the second term and the third term is changed considering that now the assignment variables are $x_{i,s}$. Constraints (3), (10), (11) are no more present; constraints (5) remain unchanged, whereas constraints (2), (4), (6)–(9) must be changed according to the new definition of $x_{i,s}$ variables. This formulation differs from the one presented by Ambrosino et al. [8] for the presence of two index assignment variables and for different rehandling constraints (9) .

When instead the stacking policy does not allow reshuffles, the model (1)–(11) must be simplified considering the same variables except $y_{i,j} \in \{0, 1\}$ that are no more present. Then, the new formulation can be obtained from model (1)–(11) by deleting the first term of cost function (1) and constraints (9).

4 Experimental Results

In order to test the effectiveness of the proposed models for the train load planning problem described in Sect. 2 and to compare them, the three models have been implemented in C#; in particular, the 0–1 linear optimization models have been solved using Cplex 12.5 and the IBM ILOG Concert library has been used for building the models from the C# language.

Our experimental analysis is based on 6 groups of instances, whose main characteristics are shown in Table 1. In particular, these 6 groups are characterized by the same number of wagons (i.e. 20), different number of containers present in the stacking area and different number of tiers (maximum number of containers in a stack). For each group, we have randomly generated 5 instances, that differ for the number of $20'$ and $40'$ containers (probabilistically generated), the weight of containers (uniformly distributed between a minimum and a maximum value, specifically defined for $20'$ and $40'$ containers), the priority assigned to containers (again, probabilistically generated, among three priority classes), and the train composition (three different types of wagons are considered, two wagon types have a capacity of 2 TEUs, the third one can carry 3 TEUs). In the last two columns of Table 1 the average capacity of the train T (expressed in TEUs) and the average number of TEUs stored in the stacking area are reported.

These 30 instances have been solved with the 3 models described above, i.e. the general formulation allowing both reshuffles and unproductive crane movements, the formulation for the case without unproductive crane movements and the one for the case without reshuffles. Results are reported in Tables 2, 3 and 4. Each table shows the size of the solved model (i.e. number of variables and constraints), the value of the objective function, the optimality gap expressed in percentage, and

Table 1 Characteristics of the groups of instances

Instances	# containers	# wagons	# tiers	T	TEUs in stacking area
1–5	30	20	4	46.4	39.2
6–10	30	20	6	47.0	43.2
11–15	40	20	4	46.2	56.8
16–20	40	20	6	47.6	58.0
21–25	50	20	4	47.0	77.6
26-30	50	20	6	46.4	74.4

the number of unproductive movements (i.e. number of reshuffles R and number of crane movements M). Please note that the value of the objective function is negative since the constant component of the objective function (1) has not been added in the models in the implementation.

The last 3 columns are useful for understanding the goodness of the obtained solutions in terms of train utilization and "quality" of loaded containers. In particular, L is the percentage ratio between the number of TEUs loaded and the capacity of the train, $\bar{L}$ represents the percentage ratio between the number of TEUs loaded and the TEUs stored in the stacking area, and P is the percentage ratio between the sum of the priority of the loaded containers and the total priority of containers present in the stacking area. The optimality gap is computed as the ratio between (objective function value-lower bound) and (-lower bound). Finally, each row of these tables reports the average data of the five solved instances.

The general model (1)–(11) seems to be very difficult to solve. In 3600 s in some cases the solver is not able to obtain a solution (i.e. one instance of group 16–20, one of group 21–25 and two instances of group 26–30 are not solved). It is worth noting that data reported in Table 2 are obtained by fixing the same weights for reshuffles and unproductive crane movements in the objective function; anyway, the difficulty in solving this model does not change also varying these two weights.

Instead, the case of model without unproductive crane movements is completely different: instances are always solved up to optimality in very few seconds. The related results are shown in Table 3, where also the CPU time in seconds is reported. Except for the instances of the last two groups (21–25 and 26–30) the number of reshuffles is generally very low.

Table 4 shows the results obtained when solving the model without reshuffles with a time limit of 3600 s. The solutions obtained with this model are better than those obtained with the general model, and for the first two groups of instances the solutions are equivalent, in terms of TEUs loaded and priority loaded, to those obtained with the model without unproductive crane movements. The solutions of the remaining groups of instances are quite good in terms of TEUs loaded and priority loaded but are characterized by a very large number of crane movements. Moreover, the optimality gap in the worst case is 16 %.

Table 2 Results obtained with the general model (1)–(11)

Inst.	# var.	# constr.	Obj.	Gap	R	M	L	$\bar{L}$	P
1–5	73166.2	422.4	−1043.0	13	4.4	68.6	76.65	90.45	93.21
6–10	68397.8	461.0	−1225.6	6	5.2	33.2	81.87	88.84	85.09
11–15	85519.6	447.2	−1003.1	41	3.6	83.3	71.07	55.49	62.85
16–20	92797.0	498.6	−682.4	50	10.0	28.6	36.83	28.65	50.11
21–25	99131.6	479.0	−989.1	48	1.0	43.9	48.75	27.52	47.80
26–30	102520.2	520.4	−929.1	30	6.2	40.7	49.35	28.66	39.34

Table 3 Results obtained with the model without unproductive crane movements

Inst.	# var.	# constr.	Obj.	Time	Gap	R	M	L	$\bar{L}$	P
1–5	1837.0	285.2	−1197.0	1.54	0	0.0	–	84.28	99.57	99.85
6–10	1744.2	322.0	−1287.8	1.39	0	2.2	–	85.97	94.12	97.83
11–15	2130.0	310.6	−1621.8	3.88	0	4.2	–	100.00	82.10	93.67
16–20	2273.4	357.8	−1700.0	8.44	0	6.0	–	98.78	83.07	93.16
21–25	2402.8	340.0	−1960.2	2.73	0	9.8	–	100.00	60.96	82.53
26–30	2533.4	383.2	−1883.4	4.46	0	17.6	–	100.00	63.24	85.76

Table 4 Results obtained with the model without reshuffles

Inst.	# var.	# constr.	Obj.	Gap	R	M	L	$\bar{L}$	P
1–5	73123.2	379.4	−1196.10	0	–	0.9	84.28	99.57	99.85
6–10	68322.8	386.0	−1287.70	1	–	2.3	85.97	94.12	97.83
11–15	85459.6	387.2	−1579.20	8	–	28.8	97.45	79.60	95.34
16–20	92701.0	402.6	−1643.70	7	–	48.3	95.92	80.03	92.60
21–25	99058.6	406.0	−1847.30	16	–	66.7	94.50	57.43	80.18
26–30	102399.2	399.4	−1855.60	10	–	43.4	99.61	62.95	85.66

5 Conclusions

In this chapter different models for solving a particular train load planning problem are presented. Results obtained with an extensive experimental campaign show that the general model is very difficult to be solved, whilst the simpler model that enable only reshuffles in the staking area is always solved up to optimality. A constructive heuristic can be used in order to provide a good solution in very few seconds and to avoid expensive unproductive movements. Moreover, it seems that a promising approach is solving the model where only reshuffles are permitted and then applying a local search in order to improve either the load train quality, in cases characterized by a 100 % of TEUs loaded on the train, or the percentage of TEUs loaded in other cases. These ideas will be the focus of a future work.

Acknowledgments We would like to thank our colleague Davide Anghinolfi for his patience and precious support in the implementation phase. The libraries in C# he developed have been very useful and helpful for the experimental tests reported in this work.

References

1. Vis, I.F.A., de Koster, R.: Transshipment of containers at a container terminal: an overview. Eur. J. Oper. Res. **147**, 1–16 (2003)
2. Steenken, D., Voss, S., Stahlbock, R.: Container terminal operation and operations research—a classification and literature review. OR Spectrum **26**, 3–49 (2004)
3. Stahlbock, R., Voss, S.: Operations research at container terminals: a literature update. OR Spectrum **30**, 1–52 (2008)
4. Bostel, N., Dejax, P.: Models and algorithms for container allocation problems on trains in a rapid transshipment shunting yard. Transp. Sci. **32**, 370–379 (1998)
5. Corry, P., Kozan, E.: An assignment model for dynamic load planning of intermodal trains. Comput. Oper. Res. **33**, 1–17 (2006)
6. Corry, P., Kozan, E.: Optimised loading patterns for intermodal trains. OR Spectrum **30**, 721–750 (2008)
7. Bruns, F., Knust, S.: Optimized load planning of trains in intermodal transportation. OR Spectrum **34**, 511–533 (2012)
8. Ambrosino, D., Bramardi, A., Pucciano, M., Sacone, S., Siri, S.: Modeling and solving the train load planning problem in seaport container terminals. In: Proceedings of the 7th annual IEEE Conference on Automation Science and Engineering, pp. 208–213 (2011). doi:10.1109/CASE.2011.6042439
9. Ambrosino, D., Caballini, C., Siri, S.: A mathematical model to evaluate different train loading and stacking policies in a container terminal. Marit. Econ. Logistics **15**(3), 292–308 (2013)

http://www.springer.com/978-3-319-04629-7

Computer-based Modelling and Optimization in Transportation

Freire de Sousa, J.; Rossi, R. (Eds.)

2014, XI, 489 p. 135 illus., 13 illus. in color., Softcover

ISBN: 978-3-319-04629-7