# Chapter 24
# An Intercontinental Replenishment Problem: A Hybrid Approach

**Elsa Silva, António G. Ramos, Manuel Lopes, Patrícia Magalhães and José Fernando Oliveira**

**Abstract** This work addresses a case study in an intercontinental supply chain. The problem emerges in a company in Angola dedicated to the trade of consumable goods for construction building and industrial maintenance. The company in Angola sends the replenishment needs to a Portuguese company, which takes the decision of which products and in which quantities will be sent by shipping container to the company in Angola. The replenishment needs include the list of products that reached the corresponding reorder point. The decision of which products and in which quantity should take into consideration a set of practical constraints: the maximum weight of the cargo, the maximum volume the cargo and financial constraints related with the minimum value that guarantees the profitability of the business and a maximum value associated with shipping insurance. A 2-stage hybrid method is proposed. In the first stage, an integer linear programming model is used to select the products that maximise the sales potential. In the second stage, a Container Loading Algorithm is used to effectively pack the selected products in the shipping container ensuring the geometrical constraints, and safety constraints such as weight limit and stability. A new set of problem instances was generated with the 2DCPackGen problem generator, using as inputs the data collected in the company. Computational results for the

E. Silva (✉)
INESC TEC, Porto, Portugal
e-mail: emsilva@inesctec.pt

A. G. Ramos
INESC TEC and CIDEM, School of Engineering, Polytechnic of Porto, Porto, Portugal
e-mail: agr@isep.ipp.pt

M. Lopes
CIDEM, School of Engineering, Polytechnic of Porto, Porto, Portugal
e-mail: mpl@isep.ipp.pt

P. Magalhães
School of Engineering, Polytechnic of Porto, Porto, Portugal
e-mail: 111051@isep.ipp.pt

J. F. Oliveira
INESC TEC and Faculty of Engineering, University of Porto, Porto, Portugal
e-mail: jfo@fe.up.pt



A. I. F. Vaz et al. (eds.), *Operational Research*, Springer Proceedings
in Mathematics & Statistics 223, https://doi.org/10.1007/978-3-319-71583-4_24

algorithm are presented and discussed. Good results were obtained with the solution approach proposed, with an average occupation ratio of 92% of the container and an average gap of 4% for the solution of the integer linear programming model.

**Keywords** Inventory planning · Container loading · Load balance

## 24.1 Introduction

This work is based on a replenishment problem of an Angolan company based in Luanda, dedicated to the trade of products for the construction building and industrial maintenance sectors. Being one of the most expressive product categories in Portuguese exports to Angola, the commercial relations between organisations stimulates the creation of partnerships which share services and resources to boost trade.

In this context, and in logistic terms, the Angolan company created a partnership with a company in Portugal, to manage all purchases, preparation and shipping of merchandise to meet its supply needs. As the scope of business is wholesale and retail, 95% of purchases correspond to material imported from Europe and 5% represent purchases made locally in the Angolan market to meet special or urgent customer needs.

With increased operational difficulties in Angola, an improvement opportunity has been identified regarding inventory management, considering, not only the minimisation of replenishing cost, but also the impact of replenishing decisions on sales revenues. The case study presented in this work combines inventory management issues with intercontinental transport, where the main goal is to obtain an optimised replenishment solution that complies with all the specific constraints within the business context and transport mode.

In Sect. 24.2 the problem is formally defined, all the goals and constraints related to the business are presented. Section 24.3 is dedicated to the literature review related with management of inventory and resource level and container loading problems. The solution approach is presented in Sect. 24.4, the Integer Linear Programming model is defined and the Container Loading Algorithm considered for packing the products is also presented. In Sect. 24.5 the computational results obtained for the generated problem instances using the solution approach proposed are presented. Finally, in Sect. 24.6 the final conclusions are presented.

## 24.2 Problem Definition

The company focused in this study has two facilities in Angola, one retail store and one wholesale, that target consumers and businesses respectively.

In recent years the company has registered its greatest growth, however, with the increase of competition the market began to demand a higher service levels, a scenario propitious for the review of all internal processes and practises of the company, establishing new objectives and costumer service policies. The adoption of new supply chain management policies and models was the largest organisational restructuring achieved by the company, since previously the management of the supply chain depended on the feeling of the decision maker, on historical or on current demand for products.

The logistics process is one of the most complex processes that prevails among intercontinental trade. There are numerous and imponderable aspects related to bureaucracy, interests of shipping companies and the administrative and functional systems, which makes the logistics operation important in the replenishment process.

The inventory needs are issued by the Angolan company and sent to the purchasing centre that is based in Portugal, being a business partnership created for that purpose that manages the entire process of purchasing, and shipping of the needs. The warehouse in Angola stores the merchandise and replenishes the wholesale (businesses). It is also responsible for replenishing the store (customers).

The purchasing centre receives a list of products with replenishing needs, analyses the list and decides which products will be sent. The list of products is composed by the products that have reached the reorder point. The company establishes a biweekly cycle of shipment of merchandise (replenishing cycle). This management decision is based on the ability of the destination company to receive, verify, check and launch the merchandise for sale.

There is a transport capacity limitation and it is necessary to determine the volume and the weight of the products to evaluate if they meet the shipping constraints. The products are shipped in boxes with heterogeneous shapes. The maximum volume is a constraint directly related to the maximum capacity of the shipping container. The weight is also a constraint related to the type of shipping container, since the transport companies stipulate a maximum limit.

In this analysis another important element is the financing of the operation. A budget per merchandise shipping operation is defined by the company, considering the business activity and legal issues. On the one hand, a minimum value is defined to guarantee the profitability of the business. On the other hand, a maximum value is defined related to the insurance of the shipment, the maximum value that an insurance company is able to pay for the merchandise. These values, minimum and maximum, are defined by management and are guidelines that the purchasing process should follow. At this stage the problem arise, the analyst should take a decision considering the constant adjustment in the ideal quantities versus the need of replenishing.

Summing up, the replenishment process begins in Angola with the data collection from the computer system of the products that reached the reorder point. The company in Angola sends the list to the central purchasing office in Portugal that analyses and decides which products and in which quantities will be replenished. The central purchasing office analyses and manages the entire process, trying to ensure the availability of the merchandise in time for consolidation and shipping.

The merchandise is unloaded in Angola and received in the warehouse which, after the conference and launch in computer system, replenishes the store according to the needs.

The problem consists in determining the selection of products which will be replenished and in which quantities, considering financial constraints and the sales potential. Besides, it should be considered that only one shipping container will be sent and it is also required that the selected products geometrically fit within the container.

## 24.3 Related Work

This section is dedicated to review literature on inventory management related with the addressed replenishment problem and container loading problem.

Reference [3] present a review of the literature from 1989 to 2005 on Joint Replenishment Problem (JRP). Problems within the JRP use models to minimise total cost and satisfy demand. The total cost considers the production or preparation costs of products, transportation and shipping costs, inventory costs, taxes and insurance. In a multi-product problem, the decision is to determine which ideal quantities of a particular product should be bought, shipped or produced.

Reference [5] present a policy of joint replenishment of multiple products considering the sharing of resources (e.g. the same transport) with a view to improving and/or dividing fixed costs. It is a problem within the scope of the JRP aggregating the following factors: minimum quantities for each product, costs of preparation of production orders admitting minimum quantity and fixed costs of transportation. The case study considered depicts a company that sells animation products in Netherlands and Belgium and has a distribution centre in Netherlands. Production orders are issued to the manufacturer in China that in turn receives raw materials and components from other suppliers. This work presents the first approach considering joint replenishing with production orders and with minimum quantities per products in a given period. If the inventory is made by the replenishing quantities the system is controlled by the level of the product, using viable combinations for joint replenishment. The ordered quantities have to satisfy the minimum quantity for the product considering a fee for the level of service. If the replenishing quantity is determined by the transport, the transport capacity is potentiated against the previous scenario. The second approach considers joint replenishing without minimum order quantities, with intermediate stocks, shortening delivery times. For this, the company must have a supply contract with the manufacturer, reducing the production time to the minimum quantity allowed, and the system is controlled by a policy of maximum level of stock considering a certain level of service. The authors concluded that the use of intermediate stocks to relax the minimum order quantities facilitates the control of the supply chain and shortens the delivery time, achieving a 44% reduction of costs [5].

In [10] it is presented a system that supports the collection of merchandise in various geographically dispersed suppliers to the central warehouse where products are stored and finally, the distribution of the products to the retailers. The focus is on reducing inventory and transportation costs, since delivery (group of customers) or collection (group of suppliers) contains diverse merchandise. For a particular vehicle the suppliers are grouped, generating the collection orders per vehicle, and the products can not be divided by more vehicles. The focus is on the division of products into groups, vehicle collection routes and specification of replenishing quantities while minimising total shipping, vehicle routing, fixed orders and stock management costs. A branch-and-price algorithm is considered to solve small instances, however since the algorithm is not scalable, heuristics are used.

The container loading problem (CLP) can be interpreted as geometric assignment problem, in which three-dimensional boxes have to be packed into three-dimensional, rectangular containers, such that a given objective function is optimized and two basic geometric feasibility conditions hold, i.e. all boxes lie entirely within the container and the boxes do not overlap. The CLP has been extensively studied in the literature with 163 papers published until 2011 [1].

A state-of-the-art review work on constraints in CLP was proposed in [1], from a exhaustive analysis of the literature, the authors concluded that there is a lack of realistic representation of practical relevant constraints. An important contribution to the representation of practical constraints was given in [6–8], which consider stability constraints closer to reality, by separating static from dynamic stability, that is, stability of the cargo during loading operations from stability during transportation.

## 24.4 Intercontinental Replenishment Algorithm

### *24.4.1 Overview*

The description of the Intercontinental Replenishment algorithm is presented. The proposed algorithm selects the products that will be replenished and proposes a feasible cargo arrangement of the products in the container, maximising the products sales potential and ensuring maximum weight limit of the cargo and cargo stability.

The products selected for replenishment are packed in boxes that will be afterwards packed in the container. Since the CLP is known as NP-hard, it is difficult to solve, and considering that besides packing boxes additional decisions have to be made, we propose a solution approach considering two steps. Firstly, an Integer Linear Programming (ILP) model is defined with the propose of selecting the products that will be replenished and in which quantities, considering as constraints the minimum and maximum financing of the company, the maximum volume that can be packed and the maximum weight with the objective of maximising the products sales potential. Secondly, a Container Loading Algorithm (CLA) is used to try to pack the selected products in the container considering that the boxes can not overlap and ensuring the stability of the cargo arrangement.

The ILP model considers only the volume of the boxes and not effectively the three physical dimensions of the boxes, which means that the CLA algorithm in some cases will not be able to pack all the selected products.

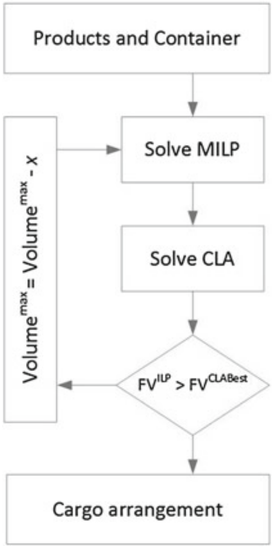


**Fig. 24.1** Architecture of the intercontinental replenishment algorithm

In Fig. 24.1 the architecture of the algorithm is presented. The algorithm starts by gathering information about the products, parameters and container characteristics, then the ILP model is solved and a set of products is selected to be shipped. The CLA tries to find a feasible packing for the selected products. At each iteration the function value (FV) of the CLA is saved, the best value is update ($FV^{best}$) and compared with $FV^{ILP}$ the current value of the solution obtained with ILP. If $FV^{ILP} > FV^{best}$, the volume constraint in the ILP model is updated by reducing the maximum volume a given $x$, in the computational experiments was considered 1%. The algorithm ends when the value of the sales potential of the solution obtained by the CLA is greater than the value of the sales potential obtained by ILP model with the maximum volume reduced.

### 24.4.2 *Integer Linear Programming Model*

The ILP model (24.2)–(24.8) is defined to maximise the sales potential of the products by selecting the products to replenish and the corresponding quantities ensuring the problem constraints. The objective function of the optimisation model considers a function called Function-Value (FV). This function is used to value products and differentiate them.

As the supply of replenishing needs is not immediate, it is important to know in advance the potential that an product represents in term of sales, in order to sustain the decision in the supply process.

Therefore, when a product reaches the reorder point, it is guaranteed that, on average, there will be sufficient stock to cover the demand until the next replenishment. In the case a product is not selected for shipping in that period, the FV informs the potential value of lost sales.

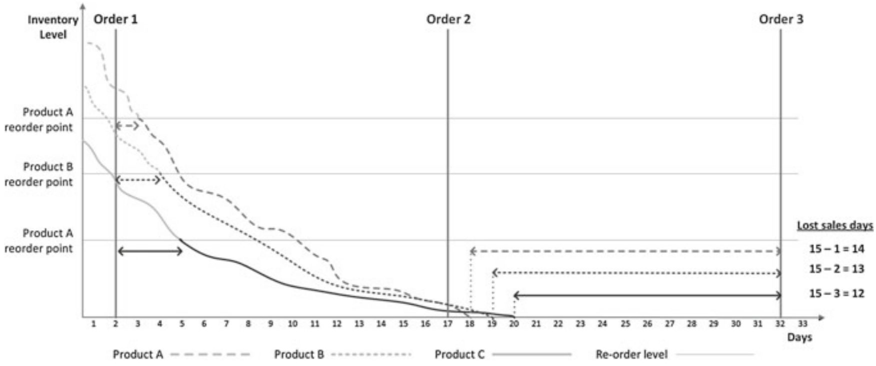


**Fig. 24.2** Replenishment example

Since the period set to send products is an input parameter, the value resulting from the FV is always analysed until the next replenishing cycle.

$A$ - Order delivery period (days)

$RP_i$ - Number of days to reach the reorder point (days)

$\bar{d}_i$ - Average daily sales (€)

$$FV_i = (A - RP_i) \times \bar{d}_i \tag{24.1}$$

In Fig. 24.2 a replenishment example of the function $FV$ is illustrated based on the stock levels of three different products. Considering the reorder date at day two, the reorder point of products A, B and C are at one, two and three days distance. Since the replenishment period is aligned with the delivery lead time, i.e., 15 days, the number of lost sales days $(A - RP_i)$ of products A, B and C are 14, 13 and 12, if the products are not replenished at order 1.

The ILP parameters and decision variables definition are presented below.

**Parameters:**

$n$ - Total number of product types
$FV_i$ - Value of the product type $i$
$wgt_i$ - Weight of the item type $i$
$QR_i$ - Maximum replenishment quantity of product type $i$
$l_i$ - Length of product type i
$w_i$ - Width of product type i
$h_i$ - Height of product type i
$v_i$ - Volume of product type i
$F_i$ - Financing of product type i
$P_{max}$ - Maximum weight admissible in the container
$V_{max}$ - Maximum volume of the container
$F_{min}$ - Minimum funding
$F_{max}$ - Maximum funding

**Decision variables:**

$x_i$ - Quantity to replenish of product $i, \forall i = 1, ..., n$

The ILP model (24.2)–(24.8) can be viewed as a knapsack formulation with additional constraints. The objective function (24.2) intends to maximise the sales potential. Constraints (24.3) ensures that the maximum weight of the container is not exceeded and, the maximum volume constraint is represented in (24.4), the range for the minimum and maximum value for the operation are ensured by constraint (24.5) and (24.6) and the maximum replenishment of each product is ensured by constraint (24.7).

$$\text{Maximize Z} = \sum_{i=1}^{n} FV_i \cdot x_i \tag{24.2}$$

$$\text{subject to:} \quad \sum_{i=1}^{n} wgt_i \cdot x_i \leq P_{max} \tag{24.3}$$

$$\sum_{i=1}^{n} v_i \cdot x_i \leq V_{max} \tag{24.4}$$

$$\sum_{i=1}^{n} F_i \cdot x_i \leq F_{max} \tag{24.5}$$

$$\sum_{i=1}^{n} F_i \cdot x_i \geq F_{min} \tag{24.6}$$

$$x_i \leq QR_i \qquad \forall i = 1, ..., n \tag{24.7}$$

$$x_i \geq 0 \text{ and integer } \forall i = 1, ..., n \tag{24.8}$$

### *24.4.3 Container Loading Algorithm*

In accordance with the typology proposed by [11] for C&P problems, the CLP addressed in this paper can be characterised as the 3-Dimensional Single Knapsack Problem (3D-SKP), with static stability constraint.

The container loading algorithm (CLA) used within the Intercontinental Replenishment Algorithm is the multi-population biased random-key genetic algorithm with static stability proposed by [7]. This algorithm was chosen since it has reported excellent benchmarking results for the CLP test instances of [2], one of the main data sets used for the 3D-SKP problem.

The CLA is a multi-population biased random-key genetic algorithm that combines a genetic algorithm, responsible for the evolution of coded solutions (chromosomes), and a constructive heuristic algorithm responsible for decoding the chromosome, generating a solution and evaluating its fitness. This constructive heuristic uses a *maximal-space* representation for the management of empty spaces, and a layer building strategy to fill those *maximal-spaces*, i.e., identical boxes are grouped along two axes in order to fill the empty space. The maximal-spaces concept, was introduced by [4], in which empty space is described as a set of non-disjoint spaces, corresponding to the largest parallelepiped shapes that can be defined in that empty space. The CLA also determines the actual physical sequence by which each box can be actually loaded inside the container by incorporating the loading algorithm proposed by [8].

A detail description of the used CLA is presented in [7].

## 24.5 Computational Results

This section presents the results of the computational experiments run to evaluate the performance of the proposed algorithm.

The algorithm was coded in Visual C++ and run on an computer with 2 Intel Xeon CPU E5-2687W at 3.1 Ghz with 128 Gigabytes of RAM running the Windows 7 Pro 64 bit operating system and the ILP model was solved with IBM ILOG Cplex 16.3 solver.

The genetic algorithm parameters used in the algorithm are similar to the ones used in [7] (Table 24.1).

### *24.5.1 Test Instances*

The problem tests used to evaluate the effectiveness of the algorithm were generated using an adaptation of 2DCPackGen problem generator proposed by [9]. In 2DCPackGen the test problem properties are controlled by a beta probability distribution, reflecting real-world characteristics. 2DCPackGen generates problem instances for the 2D and 3D Cutting and Packing problems, therefore it was adapted to include the other characteristics that are relevant for the problem considered in this case study.

The parallelepiped boxes dimensions were generated by, firstly, defining the size and shape of one of its facings, called base, and then the third dimension being

**Table 24.1** Genetic algorithm parameters used in the CLA

| Parameters | Values |
|---|---|
| Top | 15% |
| Bottom | 15% |
| Crossover probability | 0.7 |
| Population size | 2000 |
| Number of populations | 2 |
| Exchange between pop. | Every 15 generations |
| Fitness function | Maximize the % of packed container volume |
| Stopping criteria | After 1000 generations |

**Table 24.2** Ranges for the generation of problem instances

| Parameter | Minimum value | Maximum value |
|---|---|---|
| $n$ (SKU) | 1000 | 1000 |
| $QR_i$ | 1 | 30 |
| $V_i$ $(cm^3)$ | 1000 | 216 000 |
| $wgt_i$ (Kg) | 1 | 20 |
| $F_i$ (€) | 1 | 100 |
| $FV_i$ (€) | −100 | 500 |
| $P_{max}$ (Kg) | – | 21 770 |
| $F_{min}$ (€) | 40 000 | – |
| $F_{max}$ (€) | – | 75 000 |
| $V_{max}$ $(cm^3)$ | – | 30 089 620 |

materialised was the height of the box. Sixteen different types of size and shape were considered for the dimensions of the items and the other parameters were generated considering the uniform distribution.

The ranges used for the generation of the different parameters that describe the studied problem are based on the experience and knowledge of the business activity. In Table 24.2 the ranges used in the generation of each problem parameter is defined. A total of sixteen test problems with one thousand boxes were generated.

#### 24.5.1.1 Performance of the Algorithm

In Table 24.3 the computational results are presented and mainly the table is divided in three sections. The first six columns state the optimal solution obtained with the ILP model, the total number of different box types selected for replenishment ($n$), the total quantity of boxes sent to replenish ($\sum_i^n x_i$), the total weight ($wgt_{total}$), the total finance for the operation ($F_{total}$) and the value of the objective function ($Z^{*FV}$). The second section of the table (Best solution CLA), presents the results for the container loading problem, column ($V_{max}$) represents the value of the maximum volume considered in the ILP model (100% represents the total volume of the container), the percentage of volume of the container occupied by the packing arrangement obtained in the best solution of the CLA ($V_{best}$), the objective function value of the best solution of the CLA ($Z_{best}^{FV}$) and the total number of boxes packed in the container solution ($n_{total}$). The last section of the table is dedicated to the characterisation of the stopping iteration, the column ($V_{ILP}$) represents the maximum volume $V_{max}$ considered in the constraint of the maximum volume in the ILP model that obtained a solution value smaller than the best solution for the container loading with the CLA and column ($Z_{ILP}^{FV}$) represents the value of the optimal solution of the corresponding ILP. The last two columns represent the percentage of volume occupied ($V_{CLA}$) and the value of the solution ($Z_{CLA}^{FV}$) obtained by the CLA in the stopping iteration.

**Table 24.3** Computational results

| Instance | ILP ($V_{max} = 100\%$) | | | | | Best solution CLA | | | | Stopping iteration | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $n$ | $\sum_i^n x_i$ | $wgt_{total}$ | $F_{total}$ | $Z^{*FV}$ | $V_{max}(\%)$ | $V_{best}(\%)$ | $Z_{best}^{FV}$ | $n_{total}$ | $V_{ILP}(\%)$ | $Z_{ILP}^{FV}$ | $V_{CLA}(\%)$ | $Z_{CLA}^{FV}$ |
| SRLO_1 | 165 | 2504 | 21768 | 75000 | 959581 | 94 | 93.1 | 932915 | 2421 | 91 | 932413 | 90.5 | 927619 |
| SRLO_2 | 121 | 1839 | 20223 | 75000 | 732437 | 93 | 92.6 | 700181 | 1739 | 92 | 698604 | 89.9 | 678977 |
| SRLO_3 | 146 | 2170 | 21769 | 74997 | 859883 | 92 | 91.1 | 820401 | 2067 | 90 | 820079 | 88.7 | 807196 |
| SRLO_4 | 156 | 2280 | 21762 | 74991 | 896838 | 89 | 88.0 | 860560 | 2195 | 88 | 860560 | 88.0 | 860560 |
| SRLO_5 | 130 | 1911 | 19827 | 74998 | 732272 | 98 | 94.0 | 698223 | 1767 | 91 | 696665 | 89.3 | 684462 |
| SRLO_6 | 71 | 1195 | 12605 | 54703 | 465117 | 96 | 93.0 | 439194 | 1090 | 92 | 438466 | 90.9 | 433994 |
| SRLO_7 | 101 | 1587 | 17888 | 74988 | 631147 | 95 | 92.6 | 599119 | 1476 | 91 | 598600 | 89.8 | 591553 |
| SRLO_8 | 130 | 1824 | 20449 | 74999 | 679251 | 93 | 92.5 | 652572 | 1754 | 92 | 651260 | 91.0 | 644203 |
| SRLO_9 | 141 | 2142 | 21764 | 75000 | 841740 | 92 | 91.3 | 802143 | 2041 | 89 | 795335 | 87.2 | 786130 |
| SRLO_10 | 107 | 1668 | 18556 | 75000 | 667380 | 94 | 92.8 | 636809 | 1571 | 92 | 636799 | 88.0 | 597557 |
| SRLO_11 | 123 | 1923 | 19987 | 74988 | 746460 | 93 | 89.5 | 702096 | 1780 | 89 | 701956 | 86.4 | 688521 |
| SRLO_12 | 137 | 1989 | 19402 | 74986 | 755623 | 97 | 94.6 | 729230 | 1891 | 92 | 726553 | 89.7 | 708523 |
| SRLO_13 | 155 | 2430 | 21759 | 74996 | 919404 | 92 | 90.6 | 883079 | 2336 | 89 | 879538 | 86.8 | 867789 |
| SRLO_14 | 121 | 1788 | 20919 | 74999 | 698907 | 95 | 93.9 | 670338 | 1692 | 92 | 668483 | 89.1 | 646692 |
| SRLO_15 | 134 | 2052 | 21747 | 74998 | 760006 | 91 | 90.9 | 730438 | 2008 | 90 | 727961 | 89.0 | 715851 |
| SRLO_16 | 145 | 2189 | 21770 | 74999 | 867029 | 92 | 91.9 | 844840 | 2139 | 91 | 842507 | 91.0 | 842507 |

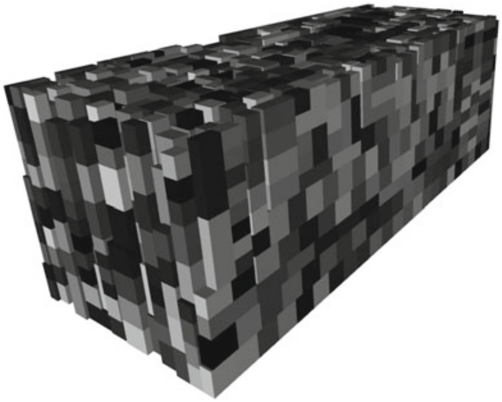

**Fig. 24.3** SRLO_1 CLA solution representation

In the solutions obtained by the ILP model the constraint related with the volume has no slack and the constraint related with maximum value for funding is almost in all instances near the maximum allowed (75 000). The exception is problem instance number 6, and the reason is related with the geometric characteristics of the boxes of this instance, which were classified as big and square and for this reason has a smaller number of items to replenish in comparison with the other problem instances.

Regarding the best solutions obtained by the CLA, the average volume occupied in the container is 92% and the total number of items packed in the container is very high, the solution with smaller number has a total of 1090 boxes. In Fig. 24.3 it is represented the best CLA solution for problem instance SRLO_1 with an occupation of 93.1% of the volume of the container.

In what concerns the quality of the value of the best solution obtained for the container loading problem with the CLA, the average difference to the optimal solution value obtained by the ILP model is 4.3% with a minimum of 2.6% in problem instance 16 and a maximum of 5.9% in problem instance 11.

## 24.6 Conclusions

In this paper we proposed a new hybrid algorithm to deal with an intercontinental replenishment problem that takes into consideration transport constraints. The ILP model selects the products that will be replenished and the respective quantities with the aim of potentiating sales. The CLA algorithms deals with the problem of packing the products in the container to be shipped. The good performance of the proposed algorithm was demonstrated by the results obtained using a set of problem instances generated considering the data encountered in practice. The results obtained also highlight the benefits of hybrid approaches to address problems with business and geometric constraints.

**Acknowledgements** The first author was supported by FCT – Fundação para a Ciência e a Tecnologia within the grant SFRH/BPD/98981/2013. The research was partially supported by ERDF European Regional Development Fund through the Operational Programme for Competitiveness and Internationalisation - COMPETE 2020 Programme within project "POCI-01-0145-FEDER-006961", and by National Funds through the Portuguese funding agency, FCT – Fundação para a Ciência e a Tecnologia as part of project "UID/EEA/50014/2013".

## References

1. A. Bortfeldt, G. Wäscher, Constraints in container loading a state-of-the-art review. Eur. J. Oper. Res. **229**(1), 1–20 (2013)
2. A. Paul Davies, E.E. Bischoff, Weight distribution considerations in container loading. Eur. J. Oper. Res. **114**(3), 509–527 (1999)
3. M. Khouja, S. Goyal, A review of the joint replenishment problem literature: 1989–2005. Eur. J. Oper. Res. **186**(1), 1–16 (2008)
4. K.K. Lai, J.W.M. Chan, Developing a simulated annealing algorithm for the cutting stock problem. Comput. Ind. Eng. **32**(1), 115–127 (1997)
5. E.P. Musalem, R. Dekker, Controlling inventories in a supply chain: a case study. Int. J. Product. Econ. **93**, 179–188 (2005)
6. A. Galrão Ramos, J.F. Oliveira, J.F. Gonçalves, M.P. Lopes, Dynamic stability metrics for the container loading problem. Transp. Res. Part C Emerg. Technol. **60**, 480–497 (2015)
7. A. Galrão Ramos, J.F. Oliveira, J.F. Gonçalves, M.P. Lopes, A container loading algorithm with static mechanical equilibrium stability constraints. Transp. Res. Part B Methodol. **91**, 565–581 (2016)
8. A. Galrão Ramos, J.F. Oliveira, M.P. Lopes, A physical packing sequence algorithm for the container loading problem with static mechanical equilibrium conditions. Int. Trans. Oper. Res. **23**(1–2), 215–238 (2016)
9. E. Silva, J.F. Oliveira, G. Wäscher, 2DCPackGen: a problem generator for two-dimensional rectangular cutting and packing problems. Eur. J. Oper. Res. **237**(3), 846–856 (2014)
10. S. Sindhuchao, H.E. Romeijn, E. Akçali, R. Boondiskulchok, An integrated inventory-routing system for multi-item joint replenishment with limited vehicle capacity. J. Glob. Optim. **32**(1), 93–118 (2005)
11. G. Wäscher, H. Haußner, H. Schumann, An improved typology of cutting and packing problems. Eur. J. Oper. Res. **183**(3), 1109–1130 (2007)