A MODEL FOR ECONOMIC AND ENVIRONMENTAL EVALUATION OF INTER-/INTRA-TERMINAL CONTAINERS FLOWS

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Abstract

European maritime ports play a fundamental role in maritime transport of containers. One of the more common problem of these ports is related to the berth congestion; in these cases solutions recommended by industry officials is to expand terminal capacity; when this solution is not available the ‘Dry port’ represents an effective alternative. The dry port is an external area directly connected with one or several seaports by rail and/or road transport. The adoption of a dry port leads to benefits on terminal congestion; depending on the distance of the dry port from the port as well as on the amount of containers stocked in the dry port area, the transport of the containers from port to dry port requires resources. In this paper, a model that allows optimizing the inter-/intra-terminal flows of the containers is proposed. The model aims at the minimization of costs and environmental impact due to the handling of containers. A full case study concerning a multi-terminal maritime system located in Port of Bari is developed.

Keywords:
Sustainable logistics, container terminal services, storage space allocation problem, dry port, mathematical model.

1 INTRODUCTION

European maritime regions are highly active in terms of trade and shipping activities, based on the gross weight of goods transported. According to European Union (EU) statistics on main EU ports, in 2015 the 25% of total gross weight of goods transported, in ‘Short Sea Shipping’ (SSS) class, occurred in Mediterranean, followed by the 26% in the North Sea. The Baltic Sea followed on the third rank, and experienced a 22%, while other regions such as the Atlantic Ocean (13%) and the Black Sea (6%) were less prevalent. The Italian ports play a fundamental role in maritime transport of containers. According to the last survey of EU Actualitix (updated to 10th January 2016), Italy is the tenth in the world rank, and the third in the Europe one, for number of port containers handled (see tab. 1).

Table 1. Worldwide container port traffic in 2016 (TEU: 20 foot equivalent units).

<table>
<thead>
<tr>
<th>RANKING</th>
<th>COUNTRY</th>
<th>DATA (TEU x 10^6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>China</td>
<td>174</td>
</tr>
<tr>
<td>2</td>
<td>United States</td>
<td>44</td>
</tr>
<tr>
<td>3</td>
<td>Singapore</td>
<td>33</td>
</tr>
<tr>
<td>4</td>
<td>South Korea</td>
<td>23</td>
</tr>
<tr>
<td>5</td>
<td>Malaysia</td>
<td>21</td>
</tr>
<tr>
<td>6</td>
<td>Japan</td>
<td>20</td>
</tr>
<tr>
<td>7</td>
<td>United Arab Emirates</td>
<td>19</td>
</tr>
<tr>
<td>8</td>
<td>Germany</td>
<td>19</td>
</tr>
<tr>
<td>9</td>
<td>Spain</td>
<td>14</td>
</tr>
<tr>
<td>10</td>
<td>Italy</td>
<td>12</td>
</tr>
</tbody>
</table>

Transport means emissions play a strategic role in manufacturing sustainability. Costs evaluations of freight transport emissions are in EU guidelines based on Kyoto protocol. In the attempt of reducing environmental costs of transport, and thus reaching emission reduction goals stated by international agreements, severe emissions standards for new vehicles and for fuels have been adopted in EU, and new taxes on road freight transport have been introduced in some EU Countries [1]. When companies measure and evaluate their performance, sustainability is a key factor to be considered. Increasing attention has been paid to the concept of sustainable production and one of the main fields where issues regarding this have become relevant is in logistic network design and operation [2,3]. Therefore the efficiency of the international container cargo transportation system is an important economic and environmental issue. A significant contribution on this concern is provided by robotic cargo handling which increases terminal efficiency and reduces costs of manpower. Robotized gantry cranes, for moving containers, or biped robots for manipulation tasks, such as lifting and carrying heavy weights, are being adopted mainly for high volume handling. Within these applications, biped robots are required to satisfy not only the power requirements [4], but also advanced balancing and locomotion capabilities [5,6], which are critical for carrying loads [7] and that are required to physically interact with the human-made environment [8,9,10].

There are many elements that affect the efficiency of containers flow. Port congestion can arise from multiple causes, including: vessel schedule reliability, lack or unavailability of docks at some marine terminals, inefficiency of Material Handling Equipment (MHE), and many other factors. One of the more common problems is related to the berth congestion due to empty container logistics in Storage Yard (SY).

In the last years many studies were devoted to solve the gate congestion problem at container terminals. In [11] a regression model is proposed for identifying the maximum number of trucks allowed at yard block per time window consistently with the resource constraints, the available yard cranes, and truck turnaround time. Kiani et al adopt the Taylor II simulation software in order to minimize the truck congestions and reduce the truck turnaround times at marine terminals [12].

A queuing model is developed in the Consorzio Napoletano Terminal Containers (CO.NA.TE.CO), located in the Port of Naples, in order to analyze the congestion problem and to minimize the service time in the yard and in access gates [13].
Consistently with the optimization of the service level and of the energy consumption required by MHE adopted in container terminals (quay cranes, internal trucks and yard cranes), in [14] a mixed integer programming model (MIP) was developed in order to minimize the total departure delay of all vessels by means of an integrated scheduling of three types of handling equipment.

In 2009 Roso et al., introduced a new concept of dry port, as a tool for solving the congestion containers problem, rather than a simple area, directly connected to seaport(s), where customers could leave or pick the containers. Three dry port categories - close, mid-range and distant - are defined by authors and for each of them advantages and disadvantages, according to different points of view, are highlighted. In particular, the authors suggest a large distance (over 500 km) from a port when this place is near large areas of consumption and many manufacturers, then the dry port act as a distribution center. A mid-range distance (distance from around 70 km to 500 km) and close dry port (around 50 km or less distant from a port) are chosen when the port is lacking the area and its capacity cannot be increased, especially when there are no possibilities for the port to expand due to inhabited areas around or environmental restrictions [15].

Further study was developed in [16] in order to analyze and compare, under time-based perspective, the physical flows and administrative activities at the seaport terminal with and without a dry port. For this scope two ports were compared (Ports of Virginia and Göteborg) and the people directly involved in terminal management were interviewed. As a result, a list of features and consideration regarding the utilization of the dry port was obtained [17].

Nowadays most decisions regarding the utilization of dry port area, the distance form port (close, midrange, and distant), the handling of the containers, and many other aspects are based on experts opinions. In fact, if on the one hand the identification of a dry port leads to many benefits about terminal congestion, on the other hand the transport of the containers, from port to dry port, requires resource and cost. Therefore in many cases the strategy to be adopted for ensuring the optimization of containers flows and the minimization of the staked area requires additional evaluation based both on the costs (transport cost, staff cost, cost for services, etc.) and on the environmental impacts due to the handling of the containers [18,19].

The purpose of this paper is to present a model allowing to optimize the inter-intra-terminal flows minimizing the cost and the environmental impact (evaluated as Carbon Footprint Index) due to the handling of containers. The model, based on a heuristic computational algorithm for non-linear programming, is tested on a full case study concerning a multi-terminal maritime system located in the Port of Bari.

The rest of the paper is structured as follows: in Section 2 the handling material process in a port is introduced and the proposed model is described; results obtained in case of a Port of Bari are in Section 3; finally, conclusion of this work are in Section 4.

2 THE MODEL

2.1 Process description
A container terminal (terminal in the remaining of the paper) in a port is the place where container ship dock on berths and unload inbound (import) containers (empty or filled with cargo) and load outbound (export) containers. The unloading of containers from a ship consists of four main phases, summarized below:

1. The inbound containers have to be taken off the ship by means of a Quay Crane (QC), the spreader of the QC locks, lifts up and moves the containers over the dock, where the container is placed on a truck, which transport the container from Quayside to the Storage Yard (SY).
2. The containers are stored by means of one or more Material Handling Equipment (MHE), as straddle carriers, sidelifts, Reach Stackers (RS), or container lorries, according to two different storing modality: ‘storing on a chassis’ and ‘stacking on the ground’. In the first case each container is individually accessible, on the contrary with stacking on the ground (most common), the containers can be piled up, which means that not all containers are directly accessible. There are different possibilities for the layout of the SY, block and linear stack are the most common layouts [10]. A decision at the strategic level, is the identification of the MHE for the storage and the retrieval of containers from the stack; this evaluation is based on the service time to be ensured and on available resources (SY area, budget, layout adopted, etc.).
3. The containers are picked up from the SY and loaded on a truck. In case ‘stacking on the ground’ is adopted as containers storing strategy, it is very important to identify a containers handling sequence finalized to maximize the number of productive move, that represent the directly actions required for moving the container from its storage location to the truck, and minimize the number of unproductive or reshuffling move, that are the movement of a container becomes necessary to retrieve another container stored underneath it in the same stack.
4. Finally, the containers are transported from the SY to the Terminal Gatehouse (TG) where each container and its documentation are checked before leaving the port.

The flow of outbound containers (loaded from port to ship) has the reverse features, therefore requires the same activities starting from step 4 to step 1. In a container terminal, the identification and the implementation of a dry port area changes the traditional handling process of a terminal. In most cases the dry port is directly connected with one or several ports by rail and/or road transport and it provides all logistics facilities required for the shipping and the handling of the containers. This means that the outbound containers could be transferred from the dry port to the dock and directly loaded onto the ship (skipping the last three steps above described). At same time, the inbound containers after the unloading from the ship can be transported directly to a dry port. Also in this case the storing of the containers in the SY is not required. Therefore in case of a dry port implementation, the use of SY area is drastically reduced in order to avoid the congestion problems due to the storing/picking of the containers from the stockpiles.

If on the one hand the identification of a dry port leads to many benefits on terminal congestion, on the other hand the transport of the containers from port to dry port, requires resources and generate extra costs. It is extremely difficult to select the optimal strategy under economic and environmental perspective; many variables and criteria have to be considered case-by-case.
2.2 Notation and Assumption

Notation adopted in the model is listed below:

- \( N \): overall number of containers to be handled (unit).
- \( N_1 \): number of containers to be stored inside the port (unit).
- \( N_2 \): number of containers to be stored in the dry port (unit).
- \( d_x, d_y, d_z \): size of the containers (see fig. 1), to be stored (m).
- \( n_x, n_y, n_z \): number of containers stored in SY according to the \( x, y \) and \( z \)-axis respectively, defining the block configuration of the containers as showed in fig. 2 (unit).
- \( D \): distance between port and dry port (km).
- \( T_{SY} \): time required for the storage/retrieval of \( N_1 \) containers in SY (h).
- \( T_i \): time required for the transport of \( N_2 \) containers from seaport to dry port (h).
- \( t_x, t_y, t_z \): time required, according to the \( x, y \) and \( z \)-axis respectively, for handling (storage and retrieval) of \( N_1 \) containers in SY (s).
- \( T_f \): average time required for all operations finalized to docking and undocking of one container from the ship to the truck, and vice versa for outbound containers, as described in first step in Section 2.1 (h/unit).

\[ T_{w} \text{ avg. waiting time of the } N \text{ containers in the port or in the dry port, before the delivery to the customer (h)}. \]

\[ C_{MHE}/C_{TRK} \text{ hourly average cost for MHE (as subscript) and truck (TRK as subscript) adopted: the parameter includes: staff cost, tax, amortization, etc. (€/h).} \]

\[ C_{PORT} \text{ hourly average cost per square meter for rental of the SY inside the port area, the value does not include the management costs (€/h•m²).} \]

\[ C_{DP} \text{ hourly average cost per square meter for the rental of the dry port; the value does not include the management costs (€/h•m²).} \]

\[ CF_{MHE}/CF_{TRK} \text{ average } '\text{non-road}' \text{ (MHE as subscript) and 'road' (TRK as subscript) vehicles equivalent hourly emission of carbon dioxide (kgCO}_2/\text{h).} \]

\[ \rho_{MHE} \text{ average } '\text{non-road}' \text{ vehicles fuel consumption per hour (l/h).} \]

\[ \rho_{TRK} \text{ average road vehicles fuel consumption per kilometers (l/100km).} \]

\( v_n, v_l \text{ average travel (h as subscript) and lifting (v as subscript) speed of the MHE adopted in SY (m/s);} \]

\( v_{TRK} \text{ average travel speed of the truck transporting the containers from port do try port (km/h).} \]

The model is developed under the following assumptions:

- The sizes of the containers to be stored \( (d_x, d_y, \text{ and } d_z) \) are the same for all containers.
- The MHE adopted in the model for each step of the handling cycle are summarized in table 2.
- The containers are stored in SY according to a stacking on the ground strategy adopting a 'block' layout: they are stored in stockpiles of the same height and each stockpile can be accessed only by one side, according to a LIFO strategy.
- The containers handling strategy adopted for the storing of the containers in SY and for the picking of the containers from SY, is optimized in order to maximize the number of product move reducing to zero the number of reshuffling move. Consistently there are not priority rule for the containers handling cycle.
- The speed \( (v_n, v_l) \) of the RS does not depend by the weight of the container carried; for safety reason, an average speed value (for horizontal and lifting movements) equal to 50% of the maximum speed of the RS is assumed for inbound and outbound containers.
- A 'transit-point' strategy is adopted in the dry port, therefore most containers (in the model it is assumed a fraction of 80%) are not stored in the dry port, but they arrive in the dry port and are directly picked up from customers. The remaining part will be stored according to a stacking on the ground strategy, adopting a "block" layout in stockpiles of unitary height \( (n_z=1) \).

**Table 2. Material Handling Equipment adopted in the model for the container handling cycle.**

<table>
<thead>
<tr>
<th>ID</th>
<th>CONTAINER OPERATIONS</th>
<th>MHE ADOPTED</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ship-to-shore</td>
<td>Mobile Harbour Crane</td>
</tr>
<tr>
<td>2</td>
<td>Storing</td>
<td>Truck</td>
</tr>
<tr>
<td>3</td>
<td>Picking</td>
<td>RS</td>
</tr>
<tr>
<td>4</td>
<td>Transport from SY</td>
<td>Truck</td>
</tr>
<tr>
<td></td>
<td>to TG</td>
<td></td>
</tr>
</tbody>
</table>

- There are no containers stored in the SY or in the dry port to initial conditions.
- The time required for transporting containers from quayside to TG area is negligible.
• The maximum capacity load assumed for every truck does not allow transporting a number of containers exceeding to 2 units. A constant speed value and a linear distance (D) is assumed to identify the Tt value, therefore Tt=D/VTRK.

• An average consumption rate for ‘road’ and ‘non-road’ vehicles (ρMHE, ρTRK) is assumed; it does not depend on travel speed, weight of containers transported, traffic conditions, etc.

• The activities due to the transport of the containers from port or dry port to customers are excluded from the model boundaries.

• The value of the rental cost of the dry port (COP) decrease with increasing of the distance between port and dry port.

2.3 Heuristic Computational Algorithm

The model developed is based on a heuristic computational algorithm for non-linear programming that ensures the minimization of the handling costs and of the carbon footprint (CF) due to activities for storage, retrieve and transport of containers. Consistently the goal of the model is achieved by means of the identification, according to the assumptions above described, of the number of containers to be stored, respectively, in the port and in the dry port (identified with N1 and N2 values).

For this purpose the model requires the following input parameters:

• Sizes (dx, dy, dz) and overall number of containers to be handled (N).

• Technical specifications and running cost (ρMHE, ρTRK, ρvh, VN, VTRK, CMHE, TRK) of all MHE (listed in tab. 2) adopted in container handling cycle.

• Rental cost for SY and for dry port.

• Distance between port and dry port (D).

The cost function (CF) to be minimized is showed in eq. 4, where C_{PORT} and C_{DP} identify the rental costs required, respectively, for storing N1 containers in SY area (see eq. 1), and for storing N2 containers in dry port (see eq. 2). The percentage of containers stored in dry port (in this case 20% of N2) is identified as μ parameter.

As far as concern C_{TRK} it identifies the costs due to the transport of N2 containers in a dry port localized to a distance D from the port.

\[ C_{PORT} = C_{PORT} \cdot d_i \cdot d_j \cdot n_i \cdot n_j \]  \hspace{1cm} (1)

\[ C_{DP} = C_{DP} \cdot d_i \cdot d_j \cdot N_2 \]  \hspace{1cm} (2)

\[ C_{TRK} = C_{TRK} \cdot N_2 \cdot T_t \]  \hspace{1cm} (3)

\[ CF = C_{MHE} \cdot (2T_{SY} \cdot N_1 \cdot T_f) + T_u (C_{PORT} + \mu \cdot C_{DP}) + C_{TRK} \]  \hspace{1cm} (4)

T_{SY} is the time required for the handling of N1 containers (lifting up and horizontal movements by the RS) in SY; this parameter, given by eq. 5, is strictly related to the congestion of containers in SY area.

\[ T_{SY} = \frac{2}{V_h} \sum_{i=1}^{n-1} \sum_{j=1}^{n-1} (id_i + jd_j) + \frac{2}{V_h} \sum_{k=1}^{n-1} kd_i \]  \hspace{1cm} (5)

The CF estimation (CF) allows evaluating the environmental impact due to the handling of containers. In the following equation (eq. 8) the CF function to be minimized is showed, where CF_{TRK} and CF_{MHE} parameters (eq. 6 and eq. 7) depend by speed, consumption and Emission Rate (ER) of MHE adopted.

\[ CF_{TRK} = 0.1 \cdot \rho_{TRK} \cdot V_{TRK} \cdot ER \]  \hspace{1cm} (6)

\[ CF_{MHE} = \rho_{MHE} \cdot ER \]  \hspace{1cm} (7)

\[ CF = CF_{MHE} \cdot (2T_{SY} + N_1 \cdot T_f) + CF_{TRK} \cdot N_2 \cdot T_t \]  \hspace{1cm} (8)

The Er parameter identifies the amount of the tailpipe emissions of CO2 from the burning of a liter of fossil fuel; in this case the hourly average CF assumed for MHE (diesel is adopted as fuel) is equal to 39.3 kgCO2/h (CF Calculator according to www.fleetnews.co.uk).

3 THE CASE OF THE PORT OF BARI

The Port of Bari, showed in figure 3, is a port serving the metropolitan area of Bari; the municipality of Bari (Southern Italy) has activated a smart governance program by a proactive engagement of government and citizens in a series of initiatives promoted by the EU [20]. The port of Bari is traditionally considered the “Europe’s door” to the Balkan Peninsula and to the Middle East, and is a multipurpose port able to meet all operational requirements. The port of Bari is one of main node of the Scandinavian-Mediterranean (Scan-Med) Corridor linking the major urban centres in Germany and Italy to Scandinavia (Oslo, København, Stockholm, and Helsinki) and the Mediterranean (Italian seaports, Sicily and Malta). The Scan-Med Corridor covers seven EU Member States and the Norway and currently represents one of the most crucial axis for the European economy, crossing almost the whole continent from North to South.

The total area of the port amounts to 285 hectares, is characterized by an overall ground area of 452000 (m²) with a coastline of 2500 (m). The port does not have yet any dry port area, but its implementation is one of the main objectives of the expansions strategic plan. The terminal runs 24-hour operations, 7 days per week.
evaluation as 'scenario α') and the second one 25 kilometers far from the port ('scenario β'), both of them are in the industrial area of the Town.

Table 3. Model input parameters.

<table>
<thead>
<tr>
<th>CLASS PARAMETERS</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Container Information</td>
<td>𝑁=608 (units)</td>
</tr>
<tr>
<td></td>
<td>𝑑𝑥=6 (m); 𝑑𝑦=2.4 (m); 𝑑𝑧=2.9 (m)</td>
</tr>
<tr>
<td>MHE Features</td>
<td>𝑣=11 (km/h); 𝑣=0.17 (m/s)</td>
</tr>
<tr>
<td></td>
<td>𝜌=15 (l/h); 𝜌=30 (l/100km)</td>
</tr>
<tr>
<td>Area and MHE running cost</td>
<td>𝐶𝑀𝐸=170 (€/h); 𝐶𝑇𝑅𝐾=130 (€/h)</td>
</tr>
<tr>
<td></td>
<td>MAX(𝐶 ödül)=0.17 (€/hm²)</td>
</tr>
<tr>
<td></td>
<td>min(𝐶득)=0.009 (€/hm²)</td>
</tr>
<tr>
<td>Downtime</td>
<td>𝑇=120 (s/unit)</td>
</tr>
<tr>
<td></td>
<td>𝑇=24 (h)</td>
</tr>
</tbody>
</table>

The results obtained from the application of the model to the case of Bari port are in figure 5 and 6. On the basis of the input parameters, above listed, the best containers handling strategies (number of containers to be stocked in port and in dry port) are identified in order to minimizing costs and carbon footprint. It is possible to observe that, in the case of Bari Port, only three possible strategies are recognized to be effective under economical and environmental perspectives. Each of them is identified by means of a “iso-strategy” curve in which the same number of containers stocked in the port (𝑁1) and in the dry port (𝑁2) are considered while varying the distance from port to potential dry port (𝐷).

A (𝑁1=608; 𝑁2=0); B (𝑁1=456; 𝑁2=152); C (𝑁1=0; 𝑁2=608)

Figure 4. Evaluation of costs adopting different strategies for the allocation of the containers in the port and in the dry port by varying the distance between them.

It is very interesting noted that the number of items to be stocked in the port (𝑁1) increases when 𝐷 increases. Consistently it is possible to observed that in case of ‘scenario α’ the containers material strategy allowing to minimize the cost is obtained by means of the storage of most containers in the port (𝑁1=456 units) and a minimal percentage of the overall number of containers in the dry port (𝑁2=152 units), as showed by the iso-strategy curve (identified as ‘B’) in figure 4. As far as concern the environmental evaluation, the minimal carbon footprint is ensured adopting the same strategy, for 𝑁1=456 units and 𝑁2=152 units (see line ‘B’ in figure 5).

Comparing the strategy that include the adoption of the dry port with the scenario ‘as-is’ (lack of the dry port) identified by ‘A’ curve (see fig. 4 and 5), the strategy proposed by the model allows an average costs reduction of about 7%, and reduction obtained in terms of carbon footprint is about 11%.

Figure 5. Evaluation of Carbon Footprint adopting different strategies for the allocation of the containers in the port and in the dry port by varying the distance between them.

Evaluating the ‘scenario β’ (𝐷=25 km), the model does not suggest the adoption of the dry port. In fact analysing the obtained results, the minimal cost and the minimal carbon footprint, respectively, for distance over to 23 (km) and 17 (km) are ensured by stocking all the containers (𝑁=𝑁1) in SY of the port (see curve ‘A’ in fig 4 and 5).

Further considerations are related to the number of containers stored in SY according to the x, y and z-axis (𝑛, 𝑛, 𝑛), respectively. Given the number of containers to be stored in port (𝑁1), by increasing the height of the stockpile (𝑛) the area occupied by the containers (𝑇) decreases reducing the area occupied by containers in SY, on the other hand the time and the cost required for the handling of the containers (𝑇) increase. Usually the best configuration of the containers stack (𝑛, 𝑛, 𝑛) allowing to minimize the overall cost is a very complex evaluation. The adoption of the model allows to identify the more cost-effective strategy. In this case, the model identify for the ‘scenario α’ a block of containers characterized by 3 overlapping containers, and a number of containers according x and y-axes that allows the saturation of the all available SY area.

It is possible to see that in many cases, in order to minimize cost and CF, different strategies are proposed by the model. In particular, for 𝐷 less than 12 (km) the best cost-effective strategy is identified by C-curve (fig. 4) while the C* curve and B-curve (fig. 5) are , the best material handling strategies under environmental perspective. Even in the case where 𝐷 is included between 17 and 21 (km), two different strategies are proposed in order to minimize economical and environmental aspects. In fact the area required by SY or dry port does not affect the CF, but is relevant under cost perspective.

4 CONCLUSIONS

In this paper, a model allowing to optimize the inter-/intra-terminal flows due to containers handling is presented. Optimization is jointly based on environmental and cost considerations.

The application of the model to the Port of Bari showed its capabilities in identifying the optimal logistic strategies
ensuring a low CF and in optimizing the cost due to containers’ handling in SY and transport activities. Results show how it is possible to identify different strategies (with or without a dry port identification) allowing to obtain an eco-friendly solution reducing, at same time, the costs for a given number of containers to be handled.

Comparing the two scenarios considered for the port of Bari, the first one (‘scenario α’ - dry port 15 kilometers far from the port) ensures a cost and a CF reduction by adopting the recommended strategy of the model, instead the scenario β (dry port 25 kilometers far from the port) not allows an environmental and economical aspects reduction if compared to currently situation. Therefore there will not be any benefit adopting a dry port at a distance of 25 km in the case of Bari port.

The main limit of the proposed model is related to the number of solutions suggested; in many cases two solutions are obtained: one that allows to optimize costs and another ensuring the minimization of the CF. Therefore the model has to be further developed in order to include more optimization criteria in its objective function. This will led to apply it to more complex scenarios, thus ensuring greater flexibility and increasing the number of the industrial environment to be applied.

5 REFERENCES