The value of integration in logistics

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ABSTRACT

Many logistic problems arising in supply chain management, distribution and inventory management call for the integration of different components of the production/distribution system which have to be coordinated in such a way that a common objective, which can be the cost minimization or the revenue maximization, is optimized. Thus, in order to find the best management policy, one should be able to tackle the problem as a whole and to find an integrated policy that is aimed at optimizing the system behavior. However, known practices as well as the scientific literature have shown a major attitude in proposing strategies that are aimed at decomposing the system in parts and then proposing optimal policies for each single part. This clearly leads to a strategy that is far from being optimal for the global system. The aim of this work is to focus on the advantages that integrated policies can provide when used to handle production, inventory and distribution problems. We will present some cases that are mainly dealing with distribution problems and show the strategies proposed in the literature. We will also present a study on a distribution system where the inventory and the distribution costs have to be minimized.

INTRODUCTION

Logistics comprises all the activities related to the functioning of a production system or a supply chain in general. When talking about logistics many persons and professionals associate it with distribution and inventory management. However, logistics is much more than this. The *Council of Supply Chain Management Professionals* gives the following definition of *logistics*: 'Logistics management is that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers requirements'. Thus, the logistics management has an impact on all the activities of a supply chain. As these activities are linked, they need to be coordinated to guarantee a good performance of the supply chain, and the same holds for logistics. This creates the need to develop integrated management policies that tackle the system as a whole and are pursued at optimizing the global performance of the system. Nothing new: it is well known that, in order to achieve the best overall performance, one has to optimize the system behavior as a whole. However, the major practices used by both professionals and scientists are based on decomposing the system and handling single parts independently. The main reason for this is related to the fact that integration is typically too difficult to achieve. Handling the global system as a whole often leads to a too complex optimization problem. However, on the other hand, decomposition leads to a worsening of the system performance which may be substantial. In fact, if on one side decomposition generates subproblems which are often much easier to handle than the integrated problem and thus for which an optimal strategy can be devised, on the other side, what is optimal for a subproblem rarely coincides with what is optimal for the integrated problem.

In the last years, the advances in technology, information systems, decision supporting tools and scientific research have favored the trend of considering larger and larger systems. The incentive in going in this direction comes from the economic advantages that may be achieved when improving the performance of the system through the development of an integrated policy.

Integration means not only finding the best overall policy, but also finding how to implement it in such a way that all the actors of the supply chain would accept it. In fact, a policy that optimizes the performance of the entire system may create advantages for some stakeholders and penalizes some other. Thus, it is crucial to define a policy to share the benefits among all the stakeholders.

In this paper we will focus on the first step of integration, i.e., the definition of integrated policies that optimize the overall system. We will not take into account the second step which deals with the definition of how the savings/revenues of this strategy should be shared among stakeholders. In particular, we will show some examples of savings achieved by integrated policies in problems arising in distribution. We will also present a computational study on an inventory routing problem which combines distribution and inventory management.

The paper is organized as follows. In the following section we present the class of problems on which we focus our study, that is the class of routing problems. We first describe the main setting of the problems and then present three examples of integration of routing deci-

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sions with other strategic and/or operational decisions, namely, location, inventory management and loading. In Section II we present a computational study on the inventory routing problem where we show the advantages of the integrated policy with respect to different policies which optimize only a single component of the global objective. Finally, conclusions are drawn in Section III.

I. ROUTING PROBLEMS

Routing problems deal with the distribution of goods from one or several origins (suppliers) to one or several destinations (customers). Similar routing problems arise in collection problems where goods must be collected from origins and delivered to destinations. The distribution/collection operations are performed by means of a fleet of vehicles which are typically subject to a set of constraints such as capacity constraints, maximum duration of the route that a vehicle can carry out (that is related to the driver shift), starting and ending time of a route, time windows at the customers, etc. The objective is to find the vehicle routes, i.e., assign each customer to a vehicle and determine the sequence of visits of each vehicle, in such a way to minimize the operational cost which typically coincides with the total distance traveled by all vehicles. Another important component of the objective function is the total number of vehicles (and thus drivers) used to serve all customers.

Many variants of routing problems have been studied in the literature. For a survey, the reader is referred to [13]. Almost all variants of routing problems belong to the class of NP-complete problems, thus they are very complex problems for which the design of an optimal strategy is typically a hard task. This led the scientific community to follow two main research directions when dealing with routing problems. From a methodological point of view, the research has been mainly concentrated on the development of heuristic solution techniques, i.e., approaches that are aimed at providing good quality solutions without the guarantee of being optimal. This is due to the fact that the design of optimal solution methods is impractical in most routing applications. From an operational point of view, routing problems have been mainly studied as stand-alone problems, i.e., without the integration with other phases or activities of the production/distribution system they are part of. This choice is due to the fact that routing problems are already difficult in themselves, thus the effort has been focused on devising good solution techniques for the routing phase without enlarging the analysis to other operations. However, in the last years this trend has changed and the scientific literature is evolving towards the study of more integrated problems.

We now focus the study on three applications of the integration of routing decisions with other decisions taken at a strategic, tactical and operational level. At a strategic level we have the *Location Routing Problems* which combine routing and location decisions. At a tactical level we study the *Inventory Routing Problem* combining routing and inventory management. Finally, at the operational level, we analyze the *Routing Problems with Loading Constraints* where the decision on how to serve the customers is combined with the one on how to load the goods on the vehicles.

A. ***Location Routing Problems***

Following [12], *location routing* can be defined as 'location planning with tour planning aspects taken into account'. Also, in [2], it is observed that 'location/routing problems are essentially strategic decisions concerning ... facility location'. Thus, location routing problems are classified as strategic problems belonging to the research area of location theory and paying special attention to routing issues. They integrate the decisions on location of facilities, allocation of customers to facilities and definition of vehicle routes to serve such customers (see [11], [9]).

Distribution costs may play a crucial role in location decisions. In order to give an idea of how the distribution activities may influence the decision on where to locate facilities, we provide a simple example. Consider the problem where a company has three customers located in points A, B and C depicted in Figure 1. Suppose that the company has to decide where to locate a distribution center which will serve the three customers. If the company is planning to serve the three customers with a single vehicle serving the three customer together in a route, then the best place where to locate the distribution center is any point on the perimeter of triangle ABC. If instead each customer will be served independently from the others by a trip that goes directly from the distribution center to the customer and back, then the best place where to locate the distribution center is point O.

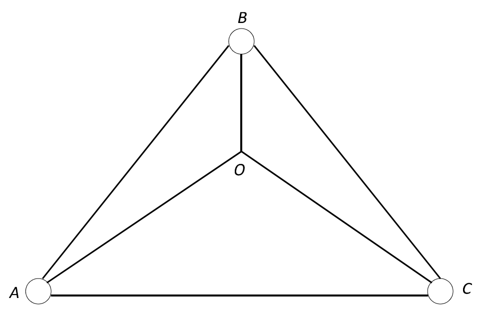

Fig. 1. Integrating location and distribution decisions

The literature on location routing problems has grown quite consistently in the last years as shown in the survey by Nagy and Salhi [12]. Location routing implies the adoption of an integrated view differing from classical location methodologies in the sense that also the routing aspects (and the related costs) are taken into account. The interrelation between facility location and routing is well known as witnessed by a pioneering paper of the sixties by Maranzana [10]. However, both practitioners and researchers have ignored this interrelation for a long time solving location problems without considering the routing aspects. Following [12], this is mainly due to three reasons:

1. There are many practical applications where location problems do not have routing aspects.
2. Location and routing belong to two different decision levels: location decisions are strategic while routing is more tactical/operational. In fact, while routes can be changed quite frequently and without incurring in big reinvestments, it is much more difficult and expensive to change facility locations.
3. Location routing problems are more difficult and less tractable than classical location problems.

Despite the previous motivations, many practical application problems call for the integration of location and routing decisions. The scientific literature shows a number of papers dealing with real-life problems where a location routing model and solution technique has been applied (see [12] for more details). Most of them deal with the distribution of goods or parcels, but there are also applications in health, military and communications.

B. ***Inventory Routing Problems***

Inventory routing problems deal with the integration of distribution planning and inventory management. They consider a supply chain where products have to be distributed from a supplier to a set of customers (typically retailers). The distribution plan has to take into account inventory constraints such as maximum inventory level at each customers (and possibly also at the supplier), no stockout or, on the contrary, possibility of backlogging, delivery frequency... The costs of the system typically include inventory costs at the supplier and at the customers and distribution costs. Two opposite policies may be thought of, and have been studied in the literature, when dealing with such a system:

- The *Retailer-Managed Inventory* (RMI) policy: in this policy, each customer (retailer) decides when he/she wants to be served and the quantity of product he/she wants to receive. The supplier plans the distribution on the basis on the decisions taken by all customers.
- The *Vendor-Managed Inventory* (VMI) policy: in this policy, the supplier monitors the inventory of each customer and determines its replenishment policy. At the same time, he/she defines the distribution plan.

The RMI policy is a decentralized policy favoring the solution that maximizes the customers benefits. However, this policy may impose on the supplier constraints that increase its costs and thus, as a consequence, the costs of the product/service to its customers. The VMI policy can be seen as an integrated and centralized policy where the supplier is responsible for the management of the entire system. Obviously, the benefit generated from such a policy depends on the objective of the supplier: he/she may take into account the global cost of the overall system or he/she may focus and give priority on some components of the system.

As pointed out in [5] and [6], the number of papers dealing with the VMI policy is growing. This is due to the advantages coming from the application of an integrated solution approach which is able to reduce the system costs.

In order to show the advantages of a VMI with respect to the RMI policy, consider the following simple example. A supply chain is formed by a supplier with a single warehouse which is used to serve three customers. The distribution plan has to be determined for the following 3 days. Each customer has a daily demand of 1 unit of product. The maximum inventory level at each customer is equal to 3 and no stockout is allowed. The distribution is performed through a fleet of homogeneous vehicles with a maximum capacity equal to 3 units. Each trip from the warehouse to a customer, as well as from a customer to another customer, has a cost of 1. The unitary inventory holding cost at all customers is 0.1. The inventory holding cost at the supplier is negligible. With the RMI policy, each customer is served every day with a delivery of 1 unit, as this is the policy that minimizes the inventory holding cost for each customer. This solution implies that a vehicle is used every day to deliver one unit to each customer, generating a daily distribution cost of 5 and, thus, a total distribution cost of 15 (over the three days). The inventory cost is equal to 0 as each customer receive 1 unit each day which is immediately consumed by the daily demand. Thus, the overall cost is 15. In the case of a VMI policy where the objective is to minimize the global system cost, the best solution is to send three vehicles from the warehouse to each customer on the first day, each delivering 3 unit to the customer. The distribution cost is 6. The inventory holding cost at each customer is equal to 0.3: on the second day the inventory level is equal to 2 units (3 units delivered on the first day minus 1 unit consumed at the first day) leading a holding cost of 0.2, while on the third day the inventory level is 1 and the corresponding holding cost is 0.1. Thus, the overall cost is 6.9.

The study of the potential benefits that may be achieved by an integrated policy in inventory routing problems dates back to the eighties with the pioneering paper by Bell et al. [3]. In [7] an extension of the problem is considered where production decisions are included.

In Section II, we will present a computational study to highlight the benefits that may be achieved from an integrated policy that minimizes the global cost of the system.

C. ***Routing Problems with Loading Constraints***

Routing problems with loading constraints combine routing decisions, i.e., the assignment of customers to vehicles and the definition of the sequence of visits of customers for each vehicle, with loading decisions, i.e., how to load the goods on the vehicle. This problem is encountered in many real-world transportation applications, especially when shippers deal with many items of different shapes and the loading aspect is not trivial. Examples include the distribution of furniture or mechanical components.

Routing problems with loading constraints may be classified as operational problems as they are related to the definition of the periodic distribution plan. They generalize the classical routing problems where a single product attribute is considered, namely, the weight. Thus, classical routing problems require that the total weight of the products loaded on each vehicle must be not greater than the vehicle capacity. This implies that the volume and the shape of the products do not have an influence when deciding how to assign products to vehicle. However, one may easily imagine that there exist a number of distribution problems where this assumption is not applicable.

The scientific literature classifies the routing problems with loading constraints in two main classes (see [8] and [14]):

- *Routing problems with two-dimensional loading constraints.* These problems arise in transportation applications dealing with items that cannot be stacked one on top of the other (because of their fragility or weight). This is the case of the transportation of refrigerators or pieces of catering equipment.
- *Routing problems with three-dimensional loading constraints.* In this case items can be superposed. An example is the transportation of furniture.

Loading items into two or three dimensional containers involve considerations not only on weight, shapes, fragility or possibility of superposing, but also on the order with which items are loaded on the vehicles. In fact, vehicle characteristics may influence the way items are loaded and unloaded. For example, for rear-loading vehicles, one has to first unload the items that are closer to the vehicle exit before being able to unload the ones that are on the back. These problems are called *routing problems with LIFO constraints*, meaning that items have to be unloaded with a reverse order with respect to the one used for the loading. This has a clear impact on the choice of the best way to serve the customers. As an example, consider the problem depicted in Figure 2. There are three customers and a single vehicle. The vehicle is located at a depot. Customers and depot locations are illustrated in Figure 2.c. Each customer requires a single item whose shape is depicted in Figure 2.a (the number on each item corresponds to the customer which requires it). The vehicle has a rear-loading container depicted in Figure 2.b. The three items completely occupy the container. The only way of feasibly loading all items in the vehicle is the one depicted in Figure 2.a or the opposite one, i.e., the one where item 2 is closer to the vehicle exit and item 1 is on the back. In any case, customer 3 has to be visited in between customer 1 and 2. If the LIFO constraints are ignored, an apparently better solution would be found, that consists in visiting customers 1 and 2 consecutively, as they are closer to each other with respect to customer 3. This solution however would be impossible to implement because of the existing loading constraints.

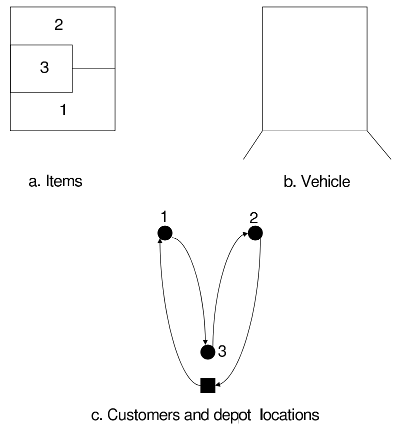

Fig. 2. A routing problem with LIFO constraints

II. COMPUTATIONAL STUDY

In this section we present a computational study focused on the analysis of the benefits of an integrated policy applied to the inventory routing problem. We consider a supply chain where a supplier, denoted as node 0, has to deliver a product to a set $\mathcal{M}$ of geographically dispersed customers with $|\mathcal{M}| = n$. A planning horizon $\mathcal{T}$ is defined and time is discretized in periods, say days. We denote as H the number of periods in the planning horizon. Each customer s faces a daily demand and defines a maximum inventory level U_s. We denote as r_{st} the demand of customer s at day t. No stockout is allowed at the customers. The product is made available at the supplier at a daily rate r_{0t} and no maximum inventory level is defined for the supplier. The distribution of the product to the customers is made through a single vehicle with a given maximum capacity C. Thus, the total quantity loaded on the vehicle in each day must not exceed the vehicle capacity. The vehicle is located at the supplier. We denote as c_{ij} the cost of going from node i (either a customer or the supplier) to node j and the unitary inventory holding cost for customer s is denoted as h_s (similarly, h_0 denotes the unitary inventory holding cost at the supplier). The system cost comprises the following three terms:

1. the distribution cost: this is given by the cost of the distance traveled by the vehicle to transport the product from the supplier to the customers in each day of the planning horizon;
2. the inventory cost at the customers: each customer faces a unitary daily inventory holding cost for the product held in inventory in each day of the planning horizon;
3. the inventory cost at the supplier: similarly to the case of the customers, the supplier faces a unitary daily inventory holding cost for the product held in inventory in each day of the planning horizon.

Our study will compare the following policies:

• VMI: the objective is to minimize the global system cost composed by all three terms previously defined.
• RMI: a hierarchical objective is established. The main objective is the minimization of the inventory cost at the customers. The secondary objective is the minimization of the sum of the distribution costs and the inventory costs at the supplier. This corresponds to a sequential optimization where first the customers optimize their own decisions and then the supplier optimizes its costs, taking the customers decisions as constraints.

A mathematical formulation of the VMI policy is presented in [1]. We report it here for the sake of completeness. The formulation makes use of the following variables:

1. B_t: inventory level at the supplier at day t;
2. I_{st}: inventory level of customer s at day t;
3. z_{it}: binary variable indicating whether node i (either a customer or the supplier) is visited at day t;
4. x_{st}: quantity delivered to customer s at day t;
5. y^t_{ij}: integer (binary) variable indicating the number of times the vehicle travels from node i (either a customer or the supplier) to node j at day t.

$$\min \quad \sum_{t\in\mathcal{T}'} h_0 B_t + \sum_{s\in\mathcal{M}}\sum_{t\in\mathcal{T}'} h_s I_{st} + \sum_{i\in\mathcal{M}'}\sum_{j\in\mathcal{M}',j<i}\sum_{t\in\mathcal{T}} c_{ij} y^t_{ij} \tag{1}$$

$$\text{s.t.} \quad B_t = B_{t-1} + r_{0t-1} - \sum_{s\in\mathcal{M}} x_{st-1} \qquad t\in\mathcal{T}' \tag{2}$$

$$B_t \ge \sum_{s\in\mathcal{M}} x_{st} \qquad t\in\mathcal{T} \tag{3}$$

$$I_{st} = I_{st-1} + x_{st-1} - r_{st-1} \qquad s\in\mathcal{M} \quad t\in\mathcal{T}' \tag{4}$$

$$I_{st} \ge 0 \qquad s\in\mathcal{M} \quad t\in\mathcal{T}' \tag{5}$$

$$x_{st} \le U_s - I_{st} \qquad s\in\mathcal{M} \quad t\in\mathcal{T} \tag{6}$$

$$x_{st} \le U_s z_{st} \qquad s\in\mathcal{M} \quad t\in\mathcal{T} \tag{7}$$

$$\sum_{s\in\mathcal{M}} x_{st} \le C \qquad t\in\mathcal{T} \tag{8}$$

$$\sum_{s\in\mathcal{M}} x_{st} \le C z_{0t} \qquad t\in\mathcal{T} \tag{9}$$

$$\sum_{j\in\mathcal{M}',j<i} y^t_{ij} + \sum_{j\in\mathcal{M}',j>i} y^t_{ji} = 2z_{it} \qquad i\in\mathcal{M}' \quad t\in\mathcal{T} \tag{10}$$

$$\sum_{i\in\mathcal{S}}\sum_{j\in\mathcal{S},j<i} y^t_{ij} \le \sum_{i\in\mathcal{S}} z_{it} - z_{kt} \qquad \mathcal{S}\subseteq\mathcal{M} \quad t\in\mathcal{T} \tag{11}$$

$$x_{st} \ge 0 \qquad s\in\mathcal{M} \quad t\in\mathcal{T} \tag{12}$$

$$y^t_{ij} \in \{0,1\} \qquad i\in\mathcal{M} \quad j\in\mathcal{M}, j<i \quad t\in\mathcal{T} \tag{13}$$

$$y^t_{i0} \in \{0,1,2\} \qquad i\in\mathcal{M} \quad t\in\mathcal{T} \tag{14}$$

$$z_{it} \in \{0,1\} \qquad i\in\mathcal{M}' \qquad t\in\mathcal{T}. \tag{15}$$

Note that $\mathcal{T}' = \mathcal{T}\cup\{H+1\}$. We consider day $H+1$ to take into account the inventory costs at the end of the planning horizon. The objective function (1) minimizes the total cost. Constraints (2)–(5) define the inventory level at the supplier and at the customers and impose to have no stock-out. (6) and (7) define the maximum inventory level at the customers. Constraints (8) and (9) are vehicle capacity constraints. (10) and (11) are routing constraints. In particular, (10) establish that if a node is visited at day t, then the vehicle has to enter and to exit from the node. Constraints (11) are subtour elimination constraints. Finally, (12)–(15) are variable definitions. Note that formulation (1)–(15) corresponds to a Mixed Integer Linear Program (MILP) and can thus be solved to optimality using a standard solution method for MILPs.

For the computational study, we use the branch-and-cut algorithm proposed in [1] and change the objective function according to the policy. This allows us to compare the optimal solution of each policy. The branch-and-cut algorithm proposed in [1] is a branch-and-bound algorithm where the subtour elimination constraints (11), which are exponential in number, are inserted only when violated, as in standard branch-and-cut algorithms for routing problems.

For the VMI policy the objective function corresponds to (1). For the RMI policy, the objective function is the following:

$$\sum_{t\in\mathcal{T}'} h_0 B_t + M\sum_{s\in\mathcal{M}}\sum_{t\in\mathcal{T}'} h_s I_{st} + \sum_{i\in\mathcal{M}'}\sum_{j\in\mathcal{M}',j<i}\sum_{t\in\mathcal{T}} c_{ij} y^t_{ij}, \tag{16}$$

where M is a large value. Thus, the optimization will first optimize the dominant part of the objective function, that is the inventory costs at the customers, and then, given that part of the solution, the costs of the supplier.

A similar study was reported in [4] where different policies were compared. The differences with respect to the current study are two-fold. Firstly, in [4] the order-up-to level policy is studied, which is a distribution policy imposing that, each time a customer is served, the quantity delivered is such that the maximum inventory level is reached. Secondly, the comparison of [4] is performed through the use of a heuristic algorithm, while in our study we compare the optimal solutions. Thus, the differences we report are more reliable in the sense that they do not depend on the quality of the solution provided by a heuristic algorithm.

Tests are performed on a subset of the instances proposed in [1] with the following characteristics:

• planning horizon: 3 and 6 days;
• number of customers: 30;
• inventory costs at the customers: randomly generated in the intervals $[0.01; 0.05]$ and $[0.1; 0.5]$;
• inventory costs at the supplier: equal to 0.03 when the inventory cost at the customers is generated in the interval $[0.01; 0.05]$ and equal to 0.3 when the inventory cost at the customers is generated in the interval $[0.1; 0.5]$;
• distribution costs: equal to the Euclidean distances between the location of the customers and the supplier, which are defined through Euclidean coordinates.

For each of the previous characteristics, 5 different instances were created for a total of 20 instances. For more details about the instances, the reader is referred to [1].

Results are shown in Figures 3-6. In Figure 3 the average total cost is reported. The three terms of the total cost are represented in the following three figures:

the inventory cost at the customers (Figure 4), the inventory cost at the supplier (Figure 5) and the distribution cost (Figure 6). Each figure reports, for each policy, the average results in the following settings:

- planning horizon of 3 days ($H = 3$);
- planning horizon of 6 days ($H = 6$);
- inventory costs at the customers randomly generated in the interval [0.01;0.05] (Low inv. cost);
- inventory costs at the customers randomly generated in the interval [0.1;0.5] (High inv. cost);
- entire test bed (Total).

Focusing on Figure 3, we can see that the RMI policy leads to solutions with a global cost that is much higher than the one obtained through the VMI policy. This is an indicator of the benefits that may be achieved by an integrated policy when considering the performance of the global system. In particular, the average increase of the total cost over all instances is 34.21% while the maximum increase is 65.61%. The highest difference is obtained in the case of a long planning horizon ($H = 6$) and low inventory cost. The longer the planning horizon is, the larger is the deterioration of the global cost due to the fact that the decisions taken by the customers about when to be served and how much to receive have a stronger impact on the distribution cost and the inventory cost at the supplier. Moreover, when the inventory cost is low, the distribution cost has a higher impact on the global cost. Thus, the RMI policy tends to produce worse solutions in terms of global cost.

Figure 4 shows how the VMI policy increases the inventory cost at the customers. This happens in particular when the planning horizon is long and when the inventory cost is high. The average increase of the inventory cost at the customers due to the VMI policy is 104.38% while the maximum increase is 173.5%. This clearly indicates that an integrated policy must be necessarily accompanied with a strategy defining how the global benefits must be shared among the stakeholders.

The difference in terms of inventory cost at the supplier is not substantial as shown in Figure 5. The average increase of the inventory cost at the supplier due to the RMI policy is 12.06% while the maximum increase is 17.32%. If we consider the distribution cost (Figure 6), the differences are remarkable: the average increase related to the RMI policy is 64.36% while the maximum increase is 83.09%. This shows that the distribution cost has a high impact on the global cost in the test instances we have studied.

To summarize, our computational study has shown that integration may indeed generate relevant benefits in terms of system optimization. However, these benefits must be properly shared among all stakeholders of the system. In fact, the reduction of the global system cost may lead to an increase of some specific components of the total cost that in turn has a negative impact on some of the stakeholders of the system.

III. CONCLUSIONS

Globalization and competition, combined with the development of information and communication tech-

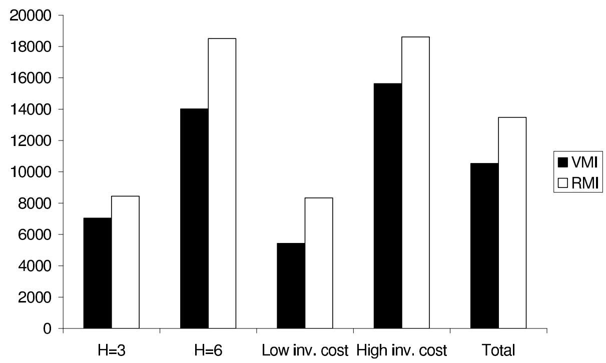

Fig. 3. Comparison of policies with respect to the total cost

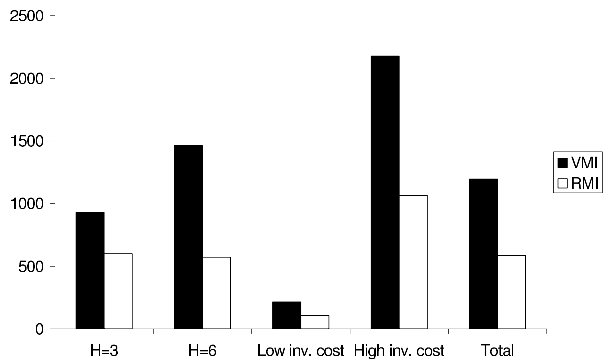

Fig. 4. Comparison of policies with respect to the inventory costs at the customers

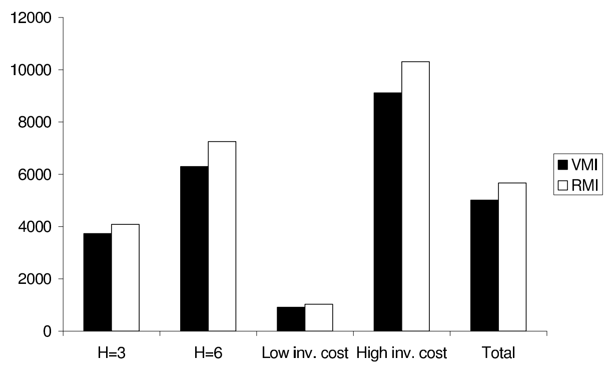

Fig. 5. Comparison of policies with respect to the inventory cost at the supplier

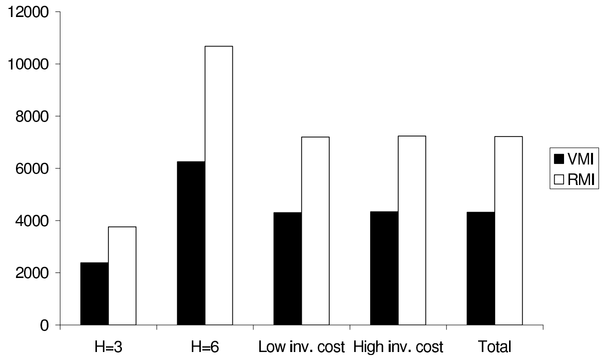

Fig. 6. Comparison of policies with respect to the distribution cost

nology, have pushed supply chains towards a global optimization process.

In the scientific community there is a general still growing trend towards modeling and solving optimization problems in logistics that jointly consider problems that were traditionally treated independently from each other. In this paper we have shown, also through a computational study, that this leads to better solutions. In particular, the computational study is focused on the inventory routing problem which combines distribution operations with inventory management. We have shown that an integrated policy which optimizes the system cost can achieve great benefits when compared to a decentralized policy where each stakeholder optimizes its own costs. These benefits generate an improved performance of the global system which can have positive returns on all the actors in case a policy is thought to properly share these benefits.

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