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Cross-Dock Location: An Airbus Helicopters Case Study

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Abstract. In this paper, we evaluate the implementation of a cross-docking strategy at Airbus Helicopters (AH). To this end, firstly, we conduct a literature review on cross-dock location, and the facility location problem (FLP). Then, we describe briefly the AH current supply chain and based on literature review we develop a mixed integer linear programming (MILP) model adapted to this case. We apply this model to optimize the AH current supply chain. Results show that total costs could be potentially reduced by 21% by implementing a cross-docking strategy at AH. Finally we conduct a sensitivity analysis on input costs in order to evaluate the robustness of the solution obtained. It is found that results obtained are sensitive to variations on the input transportation costs.

Keywords: Airbus, supply chain network design, cross-dock location, logistics, transportation

1 Introduction

Cross-docking is a logistics strategy very often used by companies in order to optimize supply chain networks. It consists in implementing intermediary facilities in order to consolidate shipments coming from several suppliers that have the same destination with no storage. This strategy has proven to be successful in industries such as the automobile industry (*i.e*. Toyota case [9]). Currently at Airbus Helicopters (AH), inbound transportation is directly managed by suppliers in 80% of the cases that leads to direct transportation to AH's warehouses. For these suppliers there's no visibility over transportation costs and transportation operations. This results in a non-optimized inbound supply chain. In this article we evaluate the possibility to implement a cross-docking strategy at AH. The aeronautic industry is characterized by small production rates (More or less 30 helicopters per year for a product line) compared to the automobile industry. In the next section, we conduct a literature review on cross-dock location, particularly we are interested in models that allow determining the optimal location of cross-docking facilities within a supply chain, that determine the product flow through the supply chain network. Then we describe the AH current supply chain and we develop a MILP cross-dock location model for the AH case. Finally we use this model in order to evaluate the implementation of a cross-docking strategy at AH.

2 Literature Review

Belle et al. [1] define cross-docking as "the process of consolidating freight with the same destination (but coming from several origins), with minimal handling and with little or no storage between unloading and loading of the goods". In that way, the main difference between cross-docking facilities and the traditional warehousing – distribution centers, is the fact that in cross-docking facilities products are temporally stored for a small amount of time. In literature, some authors define 24 hours as the storage time limit in cross-docking facilities [14]. However, in some companies, even if products are stored for a longer time, they still considering logistics platforms as cross-docks as long as "products move from supplier to storage to customer virtually untouched except for truck loading" [1]. Compared to point-to-point transportation the main advantages of cross-docking are: transportation costs reduction, consolidation of shipments and improved resource utilization. By locating cross-docks, several Less than Truck Load (LTL) shipments can be consolidated in a Full Truck Load (FTL) shipment. In this way, transportation cost is reduced due to LTL transportation distances reduction and truck capacity use rate is improved through the consolidation of LTL shipments in a FTL shipment. We can find some successful cases of cross-docking implementation as the Toyota Case [9] and the Walt Mart Case [12]. According to Belle et al. [1], mainly two factors can influence the suitability of a cross-docking strategy in a company: demand stability and unit stock out costs. Cross-docking is a good alternative when demand is stable and unit stock-out costs are low. If unit stock-out costs are important, cross-docking stills being a good solution if it is supported by appropriate planning tools and information systems.

In this study, we are particularly interested in determining the optimal location of cross-docking facilities within a supply chain network and the way the suppliers deliver their components. Facility location problem (FLP) is a well-established research area within operations research [5] which deals with this kind of problems. The simplest versions of the FLP are the p-median problem and the uncapacitated facility location problem (UFLP). The p-median problem consists in a set of customers and a set of potential facility locations distributed in a space. Each customer has its own demand, and distances or costs between each customer and each potential facility location are known. The objective is to locate N facilities at N locations of the set of potential locations in order to minimize total cost for satisfying the demand of customers. The UFLP is similar to the p-median problem. The only difference is that the number of facilities to be located is not predetermined. In the UFLP, a fixed opening cost is defined per potential facility and thus, the number of facilities located is an output of the model [10]. Moreover, the capacity of the facilities is not limited. The p-median and the UFLP problems are characterized by having deterministic parameters, a single product and a single period planning horizon.

There exists many variants of the facility location problem. The main of them are: the capacitated facility location problem [15] in which the capacity of the facilities is included in the problem, the multi-period facility location problem [6] used for problems where parameters evolve over time, the multi-product facility location problem [4] for problems were facility requirements vary in function of the type of product, the multi-level facility location problem in which location is decided at several layers of the supply chain [7], the stochastic facility location problem in which parameters behavior is modelled using probability functions and the robust facility location problem in which parameters are uncertain and there is no information about the probability function of the parameters [11]. In the AH case, parameters are deterministic, location needs to be determined only for cross-docking facilities and capacity constraints must be included. Additionally due to the strategic nature of the problem, the AH problem is a single period problem and demand can be aggregated in one single product.

Supply Chain Network Design (SCND) models can also integrate facility location decisions as well as other tactical decisions such as transportation mode selection, routing decisions, etc. However, in this study we are interested in models dealing only with location and allocation decisions.

3 Airbus Case Study

3.1 Current Supply Chain

AH has incorporated the modularity concept in its products. Hence, different modules are produced separately in the different Airbus sites: Albacete (Spain), Donauworth (Germany), Marignane (France) and Paris Le Bourget (PLB) (France). The rear fuselage is produced at Albacete, the Airframe is produced at Donauworth, the main rotor and the tail rotor are produced at Marignane and the blades are produced at PLB. Final product assembly takes place at Marignane or Donauworth. Each one of the Airbus sites has its own suppliers; they are located in three different continents: America, Africa and Europe. The scope of this study is limited to inbound flow: parts flow between suppliers and the different Airbus sites.

Recently Airbus launched a project in order to transfer all the stock to Albacete. Hence all the suppliers will deliver a warehouse at Albacete and after products will be forwarded to the final destination. We assume that this is the current scenario in our study. In other words, we evaluate the implementation of cross-docking facilities between suppliers and Albacete.

For this study, we select a panel of 152 suppliers located in Europe, America and Morocco, which are representative of product variety. Only a supplier that provides engines is excluded. This supplier delivers very expensive and bulky parts that are subject to a dedicated transportation mode managed separately. These suppliers were selected based on parts needed for the assembly of one helicopter. They represent 32% of the turnover of the company. For these suppliers we retrieved deliveries made in 2018 for Donauworth and Marignane from a database provided by the procurement department. Optimizations are conducted using this data which is representative of the AH current situation.

In the current supply chain, in 80% of the cases, suppliers manage transportation separately and AH does not have visibility over transportation operations and transportation costs (included in parts cost). Hence, the current inbound supply chain is non-optimized as a whole. Here, we evaluate the implementation of a cross-docking strategy. This would require the modification of the current AH transportation management system.

3.2 Delivery Methods and Transportation Modes

Mainly three delivery methods are used by suppliers depending on the shipment weight:

- Parcel and Courier Services (PCS): Door to door method of delivery. Freight companies suggest using this kind of solution for transport weights smaller than 70 Kg [3].
- Less than Truck Load solutions (LTL): These solutions are used when transportation weight is not significant enough to use all the transportation mode capacity. Freight transportation companies suggest using this kind of solutions for transport weights bigger than 70 kg [3] and smaller than 11 loading meters (~11 tons, [8]).
- Full Truck Load solutions (FTL): All the transportation capacity is used. This is the best and cheapest solution for big transportation quantities. Transportation companies suggest using this delivery method for transportation weights bigger than 11 loading meters (~11 tons, [8]).

Additionally, suppliers use three transportation modes: road freight, sea freight and airfreight. For suppliers located in Europe parts are 100% delivered using road freight. Suppliers located in United States and Canada deliver 100% of their parts using airfreight. There is one supplier located in Mexico: Airbus Mexico. It delivers parts for Marignane using airfreight and parts for Donauworth using sea freight for 80% of the shipments and airfreight for the remaining 20%. Finally, suppliers located in Morocco deliver 100% of their parts using sea freight.

3.3 Current Supply Chain Total Cost

We estimate total transportation cost, storage cost and work in progress (WIP) cost for the current supply chain. Concerning transportation cost, as it was mentioned before, it is not known for 80% of the suppliers. For that reason, we estimate it using UPS tariffs [13] retrieved online for the PCS shipments and DHL tariffs [2] retrieved online for LTL shipments. FTL costs are estimated based on AH inter-sites transportation costs. Transportation costs from Albacete to the final destinations (Marignane and Donauworth) are included. Regarding the storage cost only capital cost is taken into account. At Airbus it is assumed in 2018 to be equal to 10% of parts cost (figure provided by the finance department). Finally, we estimate WIP cost for sea freight shipments due to important transportation delays using the Little's Law:

$$WIP\ cost\ = Throughput\ *\ Lead\ Time * 10\%\ *\ parts\ cost \quad (1)$$

The throughput represents the demand per day (kg/ per day) and the lead time represents the transportation delay in days. The last part of the formula (1) represents the storage cost (capital cost) which is 10% of parts cost. In this case parts cost is estimated in € per kg. Current total costs are presented in Table 1. Because of **Airbus privacy policies**, total costs in the study have been normalized.

Table 1. Current Total Costs

Transportation Cost	92
Storage Cost	5
WIP Cost	3
Total Cost	100

3.4 Cross-Dock Location Model for AH

In this study we are interested in evaluating at a strategic level, if it is cost-efficient or not to implement a cross-docking consolidation strategy in a supply chain taking into account total delivery volumes (small in the AH case). In that way, the objective of this model is to support strategic decision-making process concerning transport organization. For this reason, we decide to develop a single period deterministic cross-dock location model. The supply chain considered in this case is composed by a set of suppliers N, a set of potential cross-docking facilities M and a set of warehouses P. Suppliers must satisfy warehouses demand. They have the option of delivering directly all the warehouses or passing through a cross-docking facility in order to deliver all of them. A supplier cannot deliver parts using both flow alternatives. Products are transported using PCS, LTL or FTL solutions between suppliers and warehouses and using LTL or PCS solutions between the suppliers and the cross-docking facilities. FTL solutions or LTL sea freight solutions are used between the cross-docking facilities and the warehouses (consolidation). Volume delivered by each supplier i to a warehouse k (V_{ik}), total cost of delivering products from supplier i through the cross-docking facility j (C_{ij}) and total cost of delivering products from supplier i directly to all the warehouses (C_{i0}) are known. FTL delivery frequency between the cross-docking facilities and the warehouses is fixed (FTL_{jk}), hence, storage cost at the cross-docking facilities is calculated in function of it and FTL transportation cost between the cross-docking facilities and the warehouses is fixed (t_{jk}). The MILP is presented below:

Sets

$N = \{1..n\}$: The set of suppliers.
$F = \{0\ ..\ m\}$: The set of delivery alternatives for each supplier. 0 represents delivering all the warehouses directly and *j* represents delivering all the products for all the warehouses through the cross-docking facility *j*.
$M = \{1\ ..\ m\} \subseteq F$: The set of potential cross-docking facilities.
$P = \{1\ ..\ p\}$: The set of Warehouses.

Parameters
C_{ij} $(i \in N \; and \; j \in M)$: Total cost per year of delivering all the products from supplier *i* using cross-docking facility *j*. This cost includes transportation costs between the supplier *i* and the cross-docking facility *j*, handling costs and storage cost at the cross-docking facility *j* and at the warehouses in function of FTL_{jk}.
C_{i0} $(i \in N)$: Total cost per year of delivering products directly to all the warehouses from supplier *i*. This cost includes transportation cost between the supplier *i* and all the warehouses and storage cost at all the warehouses.
V_{ik} $(i \in N \; and \; k \in P)$: Total volume (kg) delivered per year by supplier *i* to warehouse *k*.
K_{jk} $(j \in M \; and \; k \in P)$: Capacity of the transportation mode used between the cross-docking facility *j* and the warehouse *k*.
FTL_{jk} $(j \in M \; and \; k \in P)$: Fixed delivery frequency between the cross-docking facility *j* and the warehouse *k* (Times per year).
t_{jk} $(j \in M \; and \; k \in P)$: Total fixed transportation cost per year of delivering warehouse *k* from the cross-docking facility *j* with a fixed delivery frequency FTL_{jk}.
f_j $(j \in M)$: Fixed opening cost of the cross-docking facility j

Decision variables
X_{i0} $(i \in N)$: Takes a value of 1 if supplier *i* delivers all its products directly to all the warehouses, 0 otherwise.
X_{ij} $(i \in N \; and \; j \in M)$: Takes a value of 1 if supplier *i* delivers all its products through the cross-docking facility *j* to all the warehouses and 0 otherwise.
X'_{jk} $(j \in M \; and \; k \in P)$: Takes a value of 1 if the cross-docking facility *j* delivers the warehouse *k*, 0 otherwise.
Y_j $(j \in M)$: Takes a value of 1 if the cross-docking facility *j* is used, 0 otherwise.
q_{jk} $(j \in M \; and \; k \in P)$: Volume delivered from the cross-docking facility *j* to the warehouse *k*.

Model

$$\boldsymbol{Objective\ Function}: Min \sum_{i=1}^{n}\sum_{j=0}^{m} C_{ij}X_{ij} + \sum_{j=1}^{m}\sum_{k=1}^{p} t_{jk}X'_{jk} + \sum_{j=1}^{m} f_j Y_j \tag{2}$$

Subject to

$$\sum_{j=0}^{m} X_{ij} = 1 \quad \forall i \in N \tag{3}$$

$$X_{ij} \leq Y_j \quad \forall i \in N, \forall j \in M \tag{4}$$

$$q_{jk} = \sum_{i=1}^{n} X_{ij} V_{ik} \quad \forall j \in M, \forall k \in P \tag{5}$$

$$q_{jk} \leq X'_{jk} FTL_{jk} K_{jk} \quad \forall j \in M, \forall k \in P \tag{6}$$

$$X_{ij} \in \{0,1\} \quad \forall i \in N, \forall j \in F \tag{7}$$

$$Y_j \in \{0,1\} \quad \forall j \in M \tag{8}$$

$$q_{jk} \in \mathbb{R}^+ \quad \forall j \in M, \forall k \in P \tag{9}$$

$$X_{jk} \in \{0,1\} \quad \forall j \in M, \forall k \in P \tag{10}$$

The objective function (2) minimizes the sum between the total cost of delivering products from suppliers to warehouses or cross-docking facilities, the FTL transportation cost between the cross-docking facilities and the warehouses and the fixed opening costs. Constraint (3) ensures that for each supplier only one alternative is chosen between delivering products through a cross-docking facility and delivering them directly. Constraint (4) represents the fact that a supplier can deliver a cross-docking facility only if it is used. Constraint (5) ensures that products volume that goes from one cross-docking facility to one warehouse per year corresponds to the products volume delivered by suppliers using the cross-docking facility to this warehouse per year. Constraint (6) ensures that the quantity delivered from cross-docking facilities to warehouses respect the transportation mode capacity. Constraints (7-10) precise the validity domain of each decision variable.

4 Analysis of the Airbus Case Study

We run the model using Supply Chain Guru X (a supply chain design software which uses Xpress-Mosel as its mixed integer linear program solver) on the AH instance composed by 152 suppliers and one warehouse (Albacete) described in Section 3.1. Concerning cross-docking facilities, AH already counts with several distribution centers already installed in its supply chain. Based on these already existing AH distribution centers we define a set of 7 potential cross-docking facilities. In that way, there are not fixed opening costs in this case. Potential cross-docking facilities are located in: London (England), Paris (France), Toulouse (France), Saint-Etienne (France), Vitrolles (France), Zurich (Switzerland) and New York (United States). We assume that LTL sea freight is used between the cross-docking facility at New York and Albacete (taking into account volume delivered by North American suppliers) and FTL road freight is used between the rest of the cross-docking facilities and Albacete. Based on figures provided by the AH logistics department we assume that handling cost per pallet at the cross-docking facilities is equal to 16 €. We run the model for several values of FTL_{jk}:

twice per month, once per week, twice per week and three times per week. Mean running time is 11 seconds. The minimum cost is obtained for FTL_{jk} equal to 96 times per year/ twice per week and the cross-docking facilities used are Toulouse and New York. This is called the cross-docking scenario. Results are presented in Table. 2.

Table 2. Cross-docking scenario total cost results

Transportation Cost	57
Storage Cost	9
WIP Cost	6
Handling Cost	7
Total Cost	79

By using the cross-docking facilities at Toulouse and New York, with a LTL sea transportation mode between New York and Albacete, a FTL road transportation mode between Toulouse and Albacete, and a delivery frequency between the cross-docking facilities and Albacete equal to twice per week, total cost could be potentially reduced by 21%. Total cost reduction is driven by transportation cost reduction thanks to the consolidation of FTL shipments at the cross-docking facility at Toulouse and the consolidation of LTL sea freight shipments at New York (taking into account low sea freight transportation costs). 107 suppliers deliver the cross-docking facility at Toulouse and 12 suppliers deliver the cross-docking facility at New York (which explains WIP cost increase). In total 1696 tons per year are delivered to the cross-docking facilities. Supplementary storage cost in the cross-docking scenario is due to products storage at the cross-docking facilities. It is assumed that two times per week, the FTL truck used between Toulouse and Albacete, and the LTL sea transportation mode used between New York and Albacete are able to pick all the products available on stock. In other words it is assumed that workload at the cross-docking facilities is smoothed.

5 Sensitivity Analysis

In order to evaluate the robustness of the results obtained in the cross-docking scenario, we conduct a sensitivity analysis by varying input costs: transportation costs, storage cost and handling cost. We evaluate impact on total cost reduction achieved, the volume delivered to the cross-docking facilities and the cross-docking facilities used. Four levels of variation are evaluated for the input costs: -50%, -25%, +50% and + 100%. Results are presented in Fig. 1 and Fig. 2. For all the variation levels on all the input costs, the same cross-docking facilities are used: Toulouse and New York. When transportation costs are reduced by 50% total cost reduction achieved in the cross-dock location scenario decreases from 21% to 8%, and when transportation costs increase by 100% total cost reduction achieved is increased from 21% to 32%. Volume delivered per year to the cross-docking facilities is reduced by 2.5% when transportation costs are reduced by 50% and it is increased by 0.9% when transportation costs are increased by 100%. Concerning storage cost, cost reduction achieved in the cross-dock location scenario is increased from 21% to 24% when it is reduced by 50% and it is reduced from 21% to

16% when it is increased by 100%. Volume delivered per year to the cross-docking facilities is increased by 0.8% when storage cost is reduced by 50% and it is reduced by 0.1% when storage cost is increased by 100%. Finally, total cost reduction achieved in the cross-dock location scenario is increased from 21% to 25% when handling cost is reduced by 50% and it is reduced from 21% to 14% when handling cost is increased by 100%. Volume delivered per year to the cross-docking facilities does not change when handling cost is reduced by 50% and it is reduced by 0.2% when handling cost is increased by 100%.

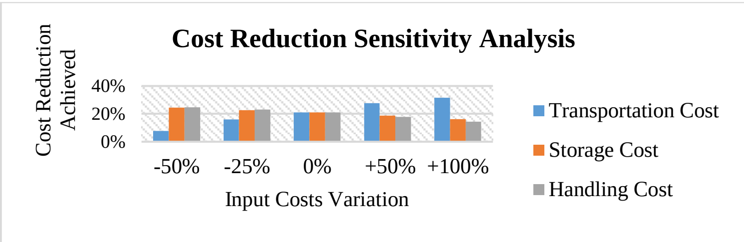

Fig. 1. Cost reduction sensitivity analysis

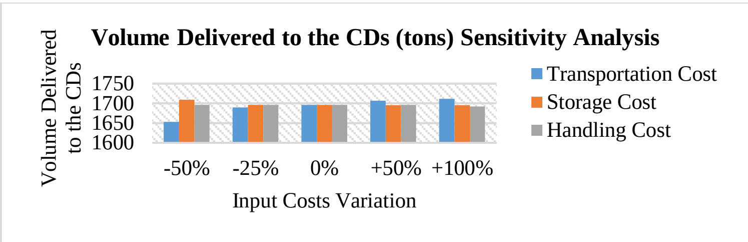

Fig. 2. Volume delivered sensitivity analysis

In conclusion, results obtained are sensitive to variations on transportation costs. Conversely, for big variations of the storage cost and the handling cost results do not change significantly.

6 Conclusions

In this article, we evaluate the implementation of a cross-docking strategy at AH, a helicopter manufacturer in the aeronautic industry, which is characterized by small production rates. To this end, based on literature, we developed a MILP cross-dock location model and we apply it to an AH instance composed by 152 suppliers, 7 potential cross-docking facilities and one warehouse (Albacete). We assume that LTL sea freight is used between the cross-docking facility at New York and Albacete and FTL road freight is used between the European cross-docking facilities and Albacete. As a result, by implementing two cross-docking facilities at Toulouse and New York, total cost could be potentially reduced by 21%. This demonstrates that a cross-docking strategy can be a cost-efficient solution in the helicopters industry despite the small production rates. Results obtained suppose that workload is smoothed at the cross-docking facilities. In order to evaluate the robustness of the results obtained, we conducted a sensitivity analysis by varying input costs. It was found that results obtained are sensitive to variations on transportation costs. Conversely, for big variations of the storage cost and the handling cost results do not change significantly. Finally, due to small delivery volume (1750 tons per year) included in this study only two cross-docking facilities are used. To go further in this analysis, it is recommendable to conduct a case study including 100% of the AH suppliers. This may increase cross-dock location cost reduction potential.

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