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EXAMINATION OF THE DEVELOPMENT POSSIBILITIES OF THE CROSS-DOCKING STRATEGY

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Abstract: Cross-docking is used as logistics strategy, where the goods are removed from the incoming vehicles to be forward directly to the outgoing vehicles. Based on the logistics processes are need more attention to minimalize the storage time or completely neglecting it. It can be used by several different companies around the world due to its economic and environmental benefits. Perhaps the most popular example is the two giant companies of American owners, Amazon and Walmart, whose main activity has a major role to play in the success of a well-planned and operated distribution logistics. With its use, the transportation costs can be highly minimized, products from several suppliers can be combined to a single shipment for economy, and lead times are reduced, and inventory costs are improved.

Keywords: *distribution, scheduling, cross-docking, strategy*

1. INTRODUCTION

Vehicle Routing problems (VRP) are becoming more and more important in the field of transportation and real-world logistics applications. Supply chain suppliers serve out the customer's demands to considering both economic and energy sustainability aspects during logistics processes. Optimum scheduling of the supply chain results more competitive and economical transportation in freight traffic [1].

Several sources of problems represent a huge professional challenge at both tactical and operational levels, including the scheduling of vehicles. If the outgoing and incoming goods traffic is not well timed and coordinated, it reduces the quality of the service of the entire system, hence the integrated vehicle scheduling is very important [2].

		Product demand rate	
		Constant and stable	Unstable
Unit inventory cost	High	Cross-docking can be implemented with appropriate systems and design tools	Tradicional warehouse usage the preferred
	Low	Cross-docking is preferred	Cross-docking can be implemented with appropriate systems and design tools

Figure 1. Preferred use of Cross-docking in different situations

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2. INVESTIGATION OF VEHICLE SCHEDULING

Three different scheduling strategies were developed:
- uncoordinated strategy,
- coordinated strategy with common headway operation,
- coordinated strategy with integer ratio headway operation.

With low inventory, the uncoordinated strategy results the lowest system cost, while the other two strategies are more suitable for a fully loaded cross-docking warehouse, in that case they result the best costs. By the way, headway is defined here as a time interval that elapses between the departure and/or arrival of two trucks from the Cross-docking facility.

The decision variables required for this are defined as follows:
- $t_i^{\alpha};t_j^{d}$ the transit time of incoming and outgoing vehicles,
- $S_i^{a}; S_j^{d}$ the vehicle capacity,
- $B_i^{\alpha}; B_j^{d}$ the unit operating costs, which includes fixed (α) and variable (β) vehicle operating costs,
- $Q_i; Q_j$ the quantities to be delivered,
- v the unit inventory cost,
- $h_i^{a}; h_d^{j}$ defines the headways (schedules) for vehicles [3].

The objective function is the minimization of operating costs, namely vehicle operation, storage, and delay costs:

$$C_t = C_B + C_I + C_W \ \rightarrow min \tag{1}$$

Description of the elements of operating costs:

$$C_B = \sum_{i=1}^{n} \frac{t_i^{\alpha}}{h_i^{\alpha}} B_i^{\alpha} + \sum_{j=1}^{m} \frac{t_j^{\alpha}}{h_j^{\alpha}} B_j^{d} = \sum_{i=1}^{n} \frac{t_i^{\alpha}}{h_i^{\alpha}} (2\alpha + \beta S_i^{\alpha}) + \sum_{j=1}^{m} \frac{t_j^{d}}{h_j^{d}} (2\alpha + \beta S_j^{d}) \tag{2}$$

$$C_I = C_I^{\alpha} + C_I^{d} \tag{3}$$

$$C_I^{\alpha} = v \sum_{i=1}^{n} \frac{h_i^{\alpha}}{2} Q_i \tag{4}$$

$$C_I^{d} = v \sum_{j=1}^{m} \frac{h_j^{d}}{2} Q_j \tag{5}$$

$$C_W = v \sum_{j=1}^{m} \frac{h_j^{d}}{2} Q_j \tag{6}$$

The first element of the three, C_B represents the operating cost of the vehicles, which includes all fixed and flexible costs, the second C_I shows the inventory cost of the products transported by each transport vehicle (α/d). The last one C_W is an additional, unplanned cost, which can be eliminated from the system with the coordinated strategy, and for the other strategies, its amount depends on the system load. Deliveries must be organized in such a way that the cargo space is filled as much as possible, and that the customers whose cargo is delivered by the truck are located on the same route. Furthermore loads must be placed in that order in which their customers will follow along the route. So, if a customer is placing the farthest from the cross-docking facility, its cargo must enter the hold firstly, thus the goods of previous destinations will be available for unloading [4, 5].

2.1. Coordinated strategy

If the implementation is well prepared, the common headway strategy's advantage is that the goods can be loaded onto the outgoing trucks without waiting, so the waiting cost for transshipments will be equal to zero. If we replace the values h_i^α and h_j^d in the main equation with the value h indicating common headway, the formula can be simplified as follows:

$$C_T = \sum_{i=1}^{n} \frac{t_i^\alpha}{h}(2\alpha + \beta S_i^\alpha) + v\sum_{i=1}^{n} \frac{h}{2} Q_i + \sum_{j=1}^{m} \frac{t_j^d}{h}\left(2\alpha + \beta S_j^d\right) + v\sum_{j=1}^{m} \frac{h}{2} Q_j \qquad (7)$$

If we solve the first derivative of the equation for h and set it equal to 0, we will get the following result:

$$h = \sqrt{\frac{\sum_{i=1}^{n} t_i^\alpha(2\alpha + \beta S_i^\alpha) + \sum_{j=1}^{m} t_j^d(2\alpha + \beta S_j^d)}{v\sum_{i=1}^{n} Q_i}} \qquad (8)$$

To make sure that the common headway h is optimal, the second derivative must be greater than 0.

$$\frac{\partial^2 C_T}{\partial h^2} = 2\left(\frac{\sum_{i=1}^{n} t_i^a(2a + \beta S_i^a) + \sum_{j=1}^{m} t_j^d(2a + \beta S_j^d)}{h^3}\right) > 0 \qquad (9)$$

If we substitute the first derivative into the formula, the total cost with the common headway strategy is the following:

$$C_t = 2 * \sqrt{v[\sum_{i=1}^{n} t_i^\alpha(2\alpha + \beta S_i^\alpha) + \sum_{j=1}^{m} t_d^j\,(2\alpha + \beta S_j^d)] \sum_{i=1}^{n} Q_i} \qquad (10)$$

The input parameters are declared based on the following:

- the quantities to be delivered are given:
- the transit time of incoming vehicles is uniformly 5 hours, the transit time of outgoing vehicles is uniformly 8 hours,
- each vehicle has a uniform capacity of 60 units,
- the fixed (α) vehicle operating cost is 8.8 pounds/hour,
- the flexible (β) vehicle operating cost is 0.066 pounds/kg-hour,
- the unit inventory cost (v) is 0.35 pounds/kg-hour [6, 7].

Any data are not necessarily realistic compared to current prices and exchange rates. In addition to the highlighted data, the coordinated strategy results the followings below:

- time elapsed between two vehicles: 2.13 hours,
- total cost of the system for this period: 676 pounds.

Table I.

Unit loads (pcs) in the allocation of individual dock doors

	Outgoing 1	***Outgoing 2***	***Outgoing 3***
Incoming 1	80	40	30
Incoming 2	25	100	25
Incoming 3	15	25	110

2.2. Uncoordinated strategy

With this strategy, transshipment without storage cannot be solved for the most part, so the extra costs resulting from the time penalty cannot be eliminated either. Each incoming and outgoing vehicle has an individual schedule time.

$$C_T = \sum_{i=1}^{n} \frac{t_i^{\alpha}}{h_i^{a}} (2\alpha + \beta S_i^{\alpha}) + v \sum_{i=1}^{n} \frac{h_i^{a}}{2} Q_i + \sum_{j=1}^{m} \frac{t_j^{d}}{h_j^{d}} \left(2\alpha + \beta S_j^{d}\right) + v \sum_{j=1}^{m} \frac{h_j^{d}}{2} Q_j + v \sum_{j=1}^{m} \frac{h_j^{d}}{2} Q_j \tag{11}$$

Based on these data, the results of this strategy can be seen below.

Table II.

Scheduling of vehicles

	Hours								
Incoming	3.0	4.9	6.3	3.9	2.6	4.9	4.5	4.9	2.5
Outgoing	3.1	2.8	2.8						

In the uncoordinated strategy, each arrival dock door and the vehicles connected to it would basically have a suitable optimal h_{opt} interval. It should be noted that if the h_{opt} value is higher than the h_{max} value of the route connected to it, then the latter must be taken into account in order to maintain the service level at the appropriate level [5, 8].

$$h_{max} = \frac{S_i^{a}}{Q_i} \tag{12}$$

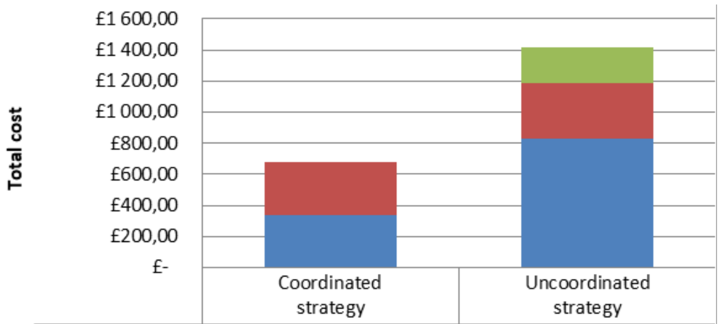
The operation of the entire system for this strategy: 1417 pounds.
The difference between the two systems:

$$\left(1 - \frac{£676}{£1417}\right) * \ 100 = 52{,}24\% \tag{13}$$

The ~50 % cost reduction is more than effective, the 60 % vehicle cost accounted for the most of it, a fraction of which was the inventory cost with less than 6 %. This is a very popular and appropriate technique in supply chain management.

Fig. 2 shows how the favorable or unfavorable development of ß (flexible vehicle operating costs) and *v* (unit inventory management costs) would affect the total cost.

It can be clearly seen, that the variable ß has a greater effect on the total cost and it can be established that the intersection of the two lines always confirms the optimal solutions.



	Coordinated strategy	Uncoordinated strategy
Time cost		£231,00
Inventory cost	£338,00	£358,00
Costs of vehicles	£338,00	£828,00

Figure 2. Comparison of coordinated and uncoordinated strategy

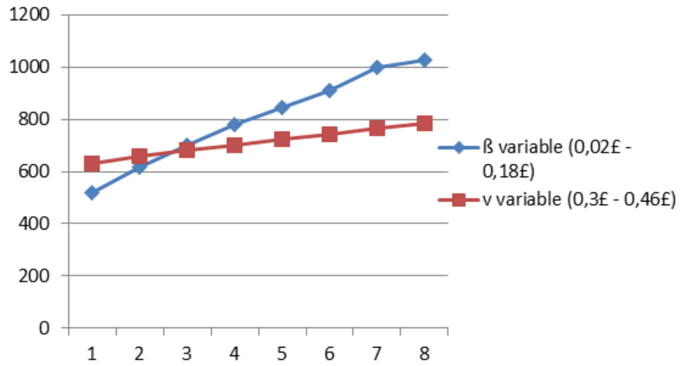


Figure 3. Comparison of two main variables affecting the total cost

3. SUMMARY

Nowadays, all members participating in supply chains strive to minimize costs to maintain their competitiveness, therefore they seize every opportunity where expenses can be reduced.

Distribution centers are a huge factor in such a complex system, including Cross-docking centers, where the goal is to move the goods as quickly as possible, preferably directly, from the incoming dock doors to the outgoing vehicles. This is managed by minimal storage and handling activities.

To reduce the internal material flow and optimally solve the scheduling, a strategic solution was developed. The uncoordinated strategy works better with low inventory and load, as the load presented in the example, the coordinated strategy shown a better solution.

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