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Designing a multi-objective nonlinear cross-docking location allocation model using genetic algorithm

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Abstract

In this study, a cross-docking system is designed at strategic and tactical levels. For making the strategic decisions, a multi-objective nonlinear location allocation model for cross-docks is presented based on a distribution location allocation model by Andreas Klose and Andreas Drexl. The model is further developed to include the whole supply chain members and the objective functions are weighted by implementing AHP. A genetic algorithm solution is designed for sample cross-dock location allocation problems. In the tactical stage, model was further simulated under two different distribution strategies to decide on the tactical parameters. As an example, the performance of the model is verified.

Keywords: Cross-docking; Cross dock; Transportation system; Supply chain design; Location allocation; Genetic algorithm; Multi-objective nonlinear model

1. Introduction

Cross-docking systems are known as distribution systems, including all the members of a supply chain, which transfer the products from suppliers to retailers through special warehouses known as cross-docks. In typical cross-docking systems, the arriving goods are transferred by vehicles and are delivered to the retailers as rapidly as possible. Goods spend very little time in storage at the warehouse, often less than 12 hours [24].

Cross docking involves holding no inventory in the distribution center but simply moving them through the distribution center when it arrives from suppliers, orders are disaggregated and sent to various stores based on the original orders that the stores placed [26]. The cross docking modeling problem can be handled as a supply chain optimization problem which in the strategic planning level, concerns the location of manufacturing and/or warehousing facilities [18].

Donald Ratliff [20] has defined cross-docking as an operation strategy at flow consolidation centers. While Bartholdi [4], describes it as a logistic technique that eliminates the storage and order picking functions of a warehouse while still allowing it to serve the receiving and shipping functions. Cross-docking has also been verified as a distribution system in which merchandise received at a distribution center is not stocked but immediately prepared for onward shipment. The inward deliveries are transferred directly from the point of reception to the point of delivery with limited or no interim storage [6]. Therefore, it has a great potential to reduce transportation cost and time without increasing inventory [20] and since there is no double handling of goods, its efficiency is high [15].

2. Literature review

The cross-docking network design models can be

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classified as an extension of generalized assignment problem or as an extension of supply-chain design model [25]. The generalized assignment problem can model a variety of real world applications in location, allocation, machine assignment and supply chains [27].

According to Melo et al. [18], in supply-chain design models, typical decisions concern the location of manufacturing and/or warehousing facilities. Although facility location and configuration of production-distribution networks have been studied for many years, a number of important real world issues have not received adequate attention. He further points out the inventory opportunities for goods, storage limitations and etc.

2.1. Supply chain location models

The facility location problems in the supply chains have been widely studied in the literature and many models have been presented in the field.

Referring to Amiri [1], an important strategic issue related to the design and operation of a supply chain system is the determination of the best sites for intermediate stocking points and the common objective is to determine the least cost of system design such that the demands of all customers are satisfied without exceeding the capacities of the warehouses and plants.

According to Lemoine [16], conceptual frameworks have been developed to explain the relationship between reconfiguration of supply chain / logistics structures and transport. As an example, Lemoine [16] presented a model comprised of five layers: material flow, transport operation, informatics operation, transport infrastructure and telecommunications infrastructure.

The design of a supply chain network is considered by Eskigun et al. [9], regarding the lead times, location of distribution facilities and the choices of transportation modes by a Capacitated Network Design Model.

The facility location problem in an integrated supply chain-based spatial interaction model is formulated by Sheu [25], in order to determine the manufacturing centers' locations and distribution centers' locations with the goal of maximizing the potential rate of return on facility investment. A multi-objective model is presented by Hugo [12], in order to determine the strategic decisions of selection, allocation and capacity expansion of processing technologies and profiles and flows of material between various components within the supply chain with the objective of maximizing the net present value of the capital investment evaluated at the end of the planning horizon and minimizing the entire impact of the network on the environment. Apaiah et al. [2] have presented a linear programming model for a location allocation in a food company, which considers possible flows and quantities of products, by-products, refuses and production schemes. The goal is to minimize the production and transportation costs with the condition of fulfilling the customer's demands.

Ma and Davidrajuh [17] have presented an iterative approach that consists of a strategic and a tactical model with the objective of maximizing the total profit and minimizing the delivery costs, inventory holding cost fixed costs. Eben-Chaime et al. [8] have presented serial scheduling methods for this real-time dynamic resource-constrained scheduling problem. The goal of their method is to maximize the percentage of jobs served on time, given the finite resource capacities.

2.2. Cross-docking location models

Ratliff et al. have established an integer-programming model, allocating the required truckloads to the cross-dock routes, while satisfying the requirements of destinations in order to minimize the number of truck miles necessary to satisfy the fixed and predefined demands of the destination spots [20]. Ratliff et al. have also established a mixed-integer linear programming model, which determines the ideal number and location of cross-docks in the network and how shipments should flow through them to minimize the average delay. Gue et al. [11] have developed a model for staging queues in cross-docks and have given simulation results for several configurations.

Bermudez and Cole [5] have presented a genetic algorithm for assigning doors in less-than-truck-load break bulk terminals aiming to minimize the total weighted travel distance. Murty et al. [19] have described a variety of inter-related decisions made during daily operations at container terminals.). Jayaram and Ross [13] have established a facility location problem, for determining the opening/operating certain number of cross-docks and origin spots by minimizing the fixed costs of opening the facilities and transportation cost. The parameters concerning the performance of a cross-dock are discussed by Bartholdi et al. which can be used in designing the cross-dock layout and can be implemented as objectives in optimizing the utility of cross-dock facilities [4]. Chen et al. [7] have presented a local search tech-

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nique for assigning deliveries in the routes of a cross-docking system, using Simulated Annealing and Tabu Search method.

In this paper, the researchers have developed a new model that can define the location and the capacity of all cross dock for all the products.

3. Methodology

This study includes two stages for designing a cross docking system: the strategic and the tactical stages.

In the strategic stage, decisions are made using the proposed multi-objective nonlinear cross-docking location allocation model. In the tactical stage the resulting network is simulated under different strategies to decide on the tactical factors.

If the results are not acceptable, the assumptions of the tactical or strategic stages are modified and the problem is solved under the new assumptions until reaching a suitable answer. The stages are shown in the Flow Chart 1.

4. The model

The presented cross-docking location allocation model is based on the CFLP[1] model by Klose et al. [2]. Necessary variables were added to the model to determine the relationships between the suppliers and facilities and the capacity of facilities. The purposes of the modified model are:

1) Locating the possible cross-docks (the possible cross-docks are either the already existing facilities or the ones to be constructed).
2) Determining their capacity for each kind of product.
3) Determining the amount and the routing of the products through the system.

The modified model is:

$$\text{Min } w_1 f_1(l_{jok}) - w_2 f_2(f_{jo}, z_{kj}) + w_3 f_3(P_{jo}) - w_4 f_4(y_j) + w_5 f_5(l_{jok}, y_j) + w_6 f_6(y_j)$$

Subject to:

$$z_{kj} - y_j \le 0, \forall j \in J \qquad \forall k \in K \qquad (1)$$

$$\sum_{j\in J} z_{kj} \ge 1 \qquad \forall k \in K \qquad (2)$$

$$\sum_{j\in J} f_{jo} \ge 1 \qquad \forall o \in O \qquad (3)$$

$$f_{jo} - y_j \le 0 \qquad \forall j \in J, \forall o \in O \qquad (4)$$

$$P_{jo} \le M_{jo} y_j \qquad \forall o \in O, \forall j \in J \qquad (5)$$

$$\sum_{j\in J} (\sum_{k\in K} l_{jok}) f_{jo} \le m_o \qquad \forall j \in J, \forall o \in O \qquad (6)$$

$$d_{ko} = \sum_{j\in J} l_{jok} z_{kj} f_{jo} \qquad \forall k \in K, \forall o \in O \qquad (7)$$

$$\sum_{k\in K} l_{jok} \le t_{jo} \qquad \forall j \in J, \forall o \in O \qquad (8)$$

$$z_{kj} = (0,1) \qquad \forall j \in J, \forall k \in K \qquad (9)$$

$$f_{jo} = (0,1) \qquad \forall j \in J, \forall k \in K \qquad (10)$$

$$y_j = (0,1) \qquad \forall j \in J \qquad (11)$$

$$P_{jo} \ge P_o^{\min} \qquad \forall j \in J \qquad (12)$$

$$P_{jo} \le P_o^{\max} \qquad \forall j \in J \qquad (13)$$

$$l_{jok} \ge 0 \qquad \forall j \in J, \forall k \in K, \forall o \in O. \qquad (14)$$

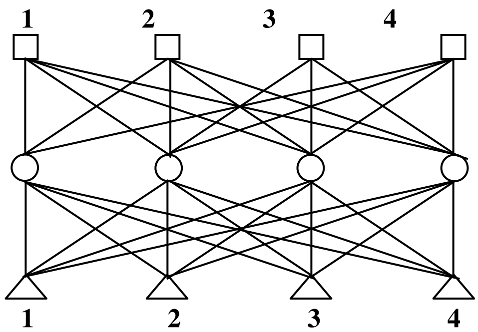

Figure 1. The schematic picture of the cross-docking system.

[1] Capacitated Facility Location Problem.
[2] Appendix I.

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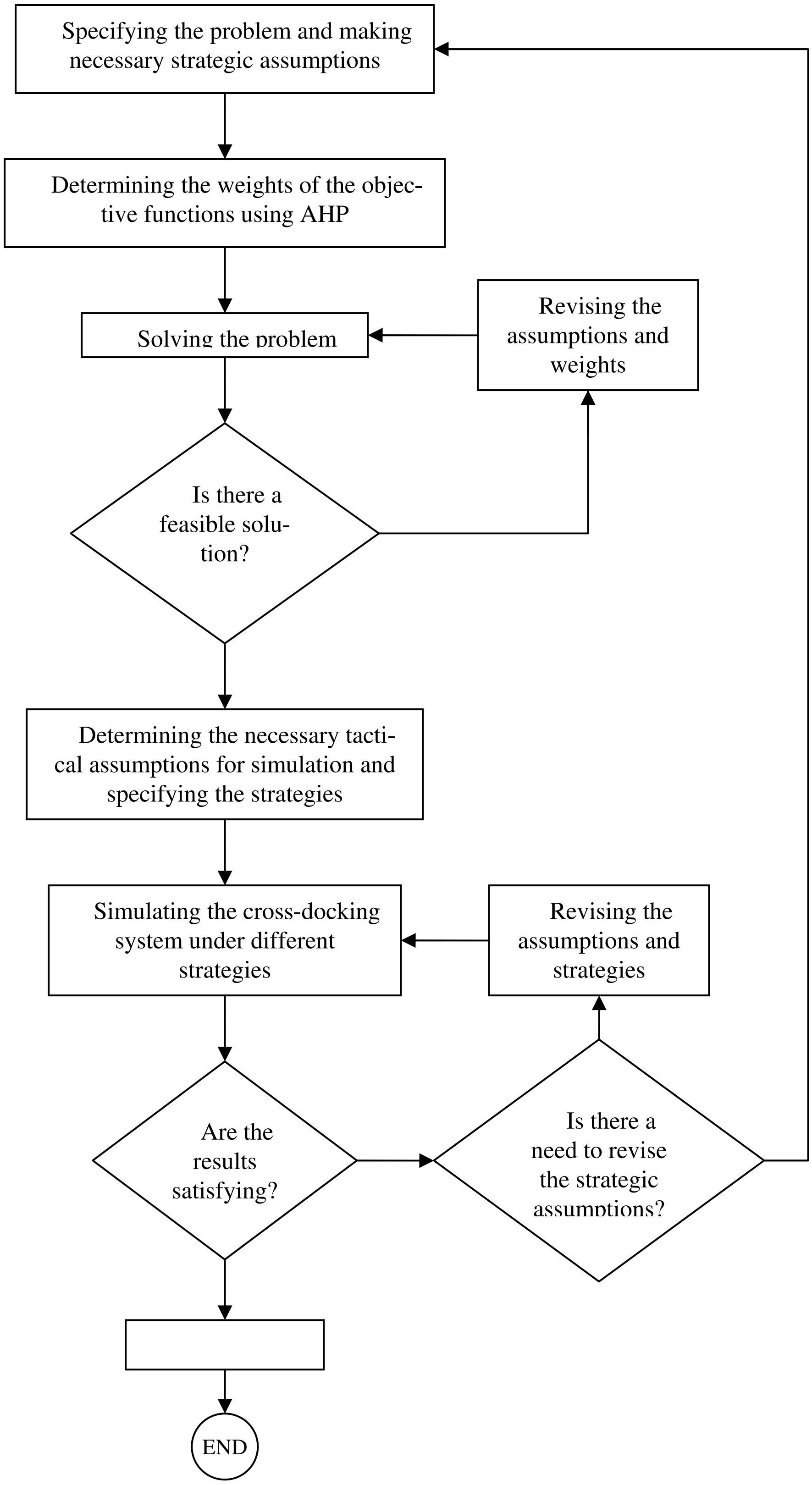

Flow Chart 1. Designing a cross docking system.

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4.1. Parameters and decision variables

The parameters of the model are:

K The set of destination nodes.

J The set of potential cross-docks.

O The set of existing origins.

d_{ko} The demand of the destination k for the products of the origin o.

t_{jo} The capacity of cross-dock j for receiving and handling product o (kg).

fc_j The fixed cost for opening/operating cross-dock j.

td_{oj} The distance between origin o to cross-dock j.

td_{oj} The distance between cross-dock j to destination k.

c_{oj} The cost of traveling a unit of distance from origin o to cross-dock j.

c_{kj} The cost of traveling a unit of distance between cross-dock j and destination k.

tc The truck capacity (kg).

w_o The weight of per unit of product o (kg).

m_o The production capacity of the origin o (kg).

P_o^{min} The minimum considered capacity of cross-dock j for product o (kg).

P_o^{max} The maximum considered capacity of cross-dock j for product o (kg).

The four decision variables of the model are:

$y_j = 1$ if the node j is chosen as a cross-dock and 0 otherwise.

P_{jo} defines the capacity of the cross-dock j for product o.

$z_{kj} = 1$ if the cross-dock j is assigned to the demand point k, and 0 otherwise.

$f_{jo} = 1$ if the cross-dock j is assigned to the origin o, and 0 otherwise.

l_{jok} indicates the amounts of the delivered good from origin o via cross-dock j to the demand point k.

4.2. Constraints

Constraint (1) in the CFLP model was modified so that each demand point can be served by at least one cross-dock. A similar constraint was added to the model for the assignment of the cross-docks to the origins. The Constraint (3) guarantees that each origin is connected to at least one cross-dock to send its products.

The necessary relationships between f_{jo} and y_j were established to guarantee that not-considered cross-docks wouldn't be assigned to an origin point in Constraint (4).

Equation (5) determines the capacity of cross-dock j for product o while guaranteeing that non-chosen cross-docks would not have a capacity more than zero. In order to guarantee the adequate transshipment of the goods in the system, the Constraints (2) and (4) of the CFLP model were substituted by Equation (6).

Constraint (6) guarantees that the handled products by the cross-docks are not more than the product capacity. The Equation (7), guarantees that the demands in the demand points are satisfied where the total amount of the goods flowing in the routes is exactly as mush as is needed in the destinations. Therefore no good is delivered to the cross-docks unless it is needed on the very same amount by a destination. Constraint (8) guarantees that the amount of dedicated good to be transferred via each cross-dock wouldn't be more than its capacity.

4.3. The objective functions

The model benefits both cross-docking design objective functions and supply chain location objective functions. The objective functions of the multi objective model are as follows:

1) Minimizing the traveled distance costs between origins and facilities, and also between facilities and destinations:

$$f_1(l_{jok}) = \sum_{o\in O}\sum_{j\in J}\sum_{k\in K}(c_{jo})(l_{jok})(td_{jo})(\frac{tc}{w_o})$$
$$+\sum_{o\in O}\sum_{j\in J}\sum_{k\in K}(c_{kj})(l_{jok})(td_{kj})(\frac{tc}{w_o}).$$

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2) Maximizing the usage of the roads with high quality:

$$f_2(f_{jo}, z_{kj}) = \sum_{j\in J}\sum_{o\in O} q_{jo} f_{jo} + \sum_{j\in J}\sum_{k\in K} q_{kj} z_{kj} ,$$

where q_{oj} and q_{kj} represent the quality of the road taken from the point the o to j and from j to k.

3) Minimizing the cost of per unit of capacity for product o of the cross-dock j:

$$f_3(P_{jo}) = \sum_{j\in J} s_o P_{jo} ,$$

where s_o represents the cost of each unit of capacity for product o.

4) Maximizing the benefits of being close to the facilities (electricity, data-links, water pipes etc.)

$$f_4(y_j) = \sum_{j\in J} g_j y_j ,$$

where g_j indicates the degree of being close to the facilities.

5) Minimizing the material handling costs in the cross-docks:

$$f_5(l_{jok}, y_j) = \sum_{o\in O}\sum_{j\in J}(\sum_{k\in K} l_{jok}) mc_{jo} y_j ,$$

where mc_{jo} represents the material handling cost for each unit of product o in cross-dock j.

6) Minimizing the fixed cost of constructing / implementing a cross-dock:

$$f_6(y_j) = \sum_{j\in J} fc_j y_j ,$$

where fc_j represents this fixed cost of constructing /implementing cross-dock j.

Since a mixture of quantitative and qualitative objective functions are used in the modified multi-objective model, a linear combination of the normalized objective functions can be considered in order to be able to estimate the objective function of the model. The weights of the objective functions can be determined using the Analytic Hierarchy Process (AHP) [3].

5. The advantages of the modified model

The modified model is located in the intersection of supply chain design models and cross-docking location allocation models, benefiting from advantages of both types.

The past researches suggest that the location decision framework used by managers, predominantly emphasized quantitative analyses that trade off transport costs, scale economies, and other cost based variables while other critical variables are considered in the modified model.

While main focus of the supply chain design models is on minimizing the costs, delays and maximizing the benefits, the modified model is a multi objective concerning the qualitative objective as well. Moreover, deciding the capacity of the cross-docks is not considered in the previous cross-docking models, which is an important decision in constructing cross-docks.

Another major advantage is considering different types of products separately while it is assumed to be a general product flow in both cross docking and supply chain design models.

When followed by scheduling, it serves best the strategic and tactical decisions in designing a cross-docking system.

As a cross-docking location allocation model, the modified model can be compared with the two models presented by Ratliff et al. known as the main and most important models in the cross-docking models.

Ratliff, et al. have developed two models for cross docking networks: 1) an integer programming model for a truck network of the US Postal Service First Class Mail transportation system [20], and 2) a mixed-integer model for determining the number and location of cross-docks in a load-driven system in an automobile delivery system [21].

The advantages of the modified model compared with these two models can be listed as follows:

- **The objective function:** The objective function of the Ratliff's first model is to minimize the number of truck-miles and that of the second model is to minimize the average delay time. While the modified model is a multi-objective, determining to optimize: the traveled distance

[3] Appendix II

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costs, costs of using the roads of poor quality, benefits of being close to the facilities (electricity, data-links, water pipes etc.), material handling costs for each type of product in the cross-docks and the fixed cost of constructing / implementing a cross-dock.

- **The constraints:** The schedule-driven cross-docking Network, considers truck capacity and the predefined flow of the demands as constraining factors. In the Schedule-driven cross-docking Network, the constraints are only dealing with the flow of the demands. While the following constraints, are considered in the modified model: the origin factories production capacity, the cross-docks capacity for each kind of deliveries, the requirements of each destination for the products of each origin.
- **The decision variables:** None of the models have considered cross-docks' capacity as a decision variable. Even the capacities of not-constructed cross-docks are assumed to be known.

6. Results

An example for a cross-docking system was defined. In the first stage, the location of the cross-docks, the capacities and the deliveries' routings through the system were determined using Genetic Algorithm. The necessary assumptions in this strategic stage were as follows: distances between the points, destinations' demands, cross-docks' opening and constructing costs, material handling costs for each product, trucks capacity etc.

The example consists of three cross-docks, two origin points and two destinations. The initial amounts of the parameters are shown in Table 1.

In the first stage, the location of the cross-docks, the capacities and the deliveries' routings through the system were determined using Genetic Algorithm [10]. In the next stage, the cross-docking system was simulated under two different strategies in order to choose the best scheduling parameters.

Necessary assumptions and parameters were considered in both stages, such as the distances between the points, destinations demands, cross-docks' opening and constructing costs, material handling costs for each product, trucks capacity, deliveries' size, lift trucks' capacities, distances between the receiving and shipping doors, traveling duration within the cross-docks, available human resource for each activity, truck traveling durations, loading and unloading times of deliveries, queuing and serving strategies, priorities in loading and unloading goods, priorities in serving the demand points and etc.

All the possible solutions of the problem were considered. The fitness functions were calculated and all the strategic parameters were defined. The fitness functions are shown in Table 2, Figures 3 and 4.

As can be seen, the solution 5 is the optimum solution. Other strategic parameters which were also defined in this stage are:

- Assignment of the cross-dock *j* to the origin *o*:

Origins

$$\text{Cross-docks}\begin{pmatrix} 0 & 1 \\ 0 & 0 \\ 1 & 1 \end{pmatrix}$$

- Assignment of the cross-dock *j* to the destination *k*:

Origins

$$\text{Destination}\begin{pmatrix} 0 & 0 & 1 \\ 1 & 0 & 1 \end{pmatrix}$$

- Amounts of the delivered product of origin *o* through cross-dock *j* to the point *k*:

Origins / Origins

$$\text{Cross-docks}\begin{pmatrix} 0 & 0 \\ 1 & 1 \\ 4000 & 3000 \end{pmatrix} \quad \begin{pmatrix} 0 & 0 \\ 1 & 1 \\ 4000 & 3000 \end{pmatrix}$$

Destination 1 / Destination 2

The best answer from the strategic stage is shown in the Figure 5.

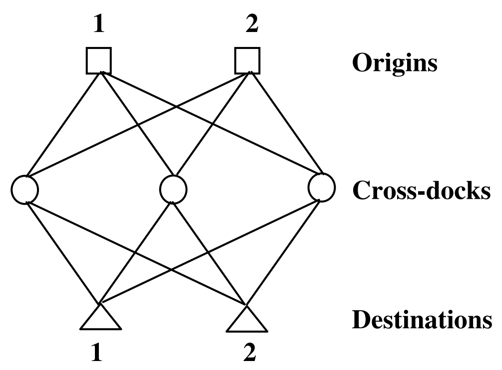

Figure 2. The cross docking model.

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Table 1. The initial amounts of the example parameters.

		o = 1 j = 1 k = 1	o = 1 j = 2 k = 1	o =1 j= 3 k = 1	o = 1 j = 1 k = 2	o = 1 j = 2 k = 2	o = 1 j = 3 k = 2	o = 2 j = 1 k = 1	O = 2 j = 2 k = 1	o = 2 j = 3 k = 1	o = 2 j = 1 k = 2	o = 2 j = 2 k = 2	o = 2 j = 3 k = 2
td_{jo}		1	0.375	0.525	1	0.375	0.525	0.625	0.250	0.075	0.625	0.250	0.075
td_{kj}		0.420	0.100	0..03	0.600	1	0.90	0.420	0.100	0..03	0.600	1	0.90
d_{ko}		4000			3000			3000			5000		
tc		10000											
c_{jo}		400	350	450				275	350	425			
c_{kj}		350	250	500	425	375	250						
q_{jo}		0.6	0.4	0.5				0.9	0.8	0.9			
q_{kj}		0.9	0.7	0.8	0.9	0.6	0.8						
mc_{jo}		0.5	0.7	0.4				1	0.9	0.8			
g_j		0.7	0.5	1.0									
fc_j		1	0.374	0.667									
w_o		20						10					
p_{jo}^{min}		10000	10000	10000				20000	10000	1500			
p_{jo}^{mx}		90000	80000	80000				90000	90000	8000			
m_o		100000						200000					

Table 2. The fitness function amounts.

Solution	1	2	3	4	5	6	7
Y matrix	001	010	011	100	101	110	111
Fitness function	0.1518	0.1432	0.135	0.139	0.0974	0.136	0.199

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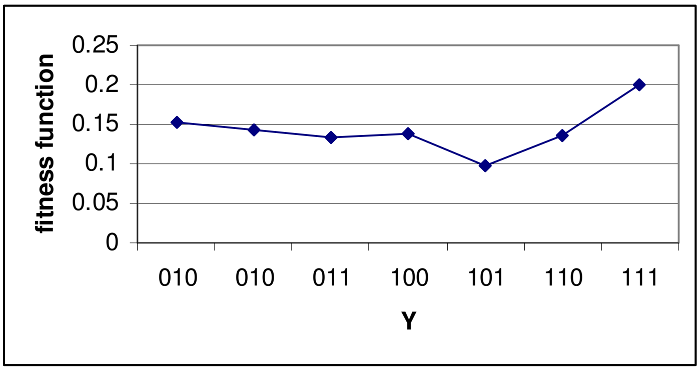

Figure 3. Fitness functions of all the possible solutions.

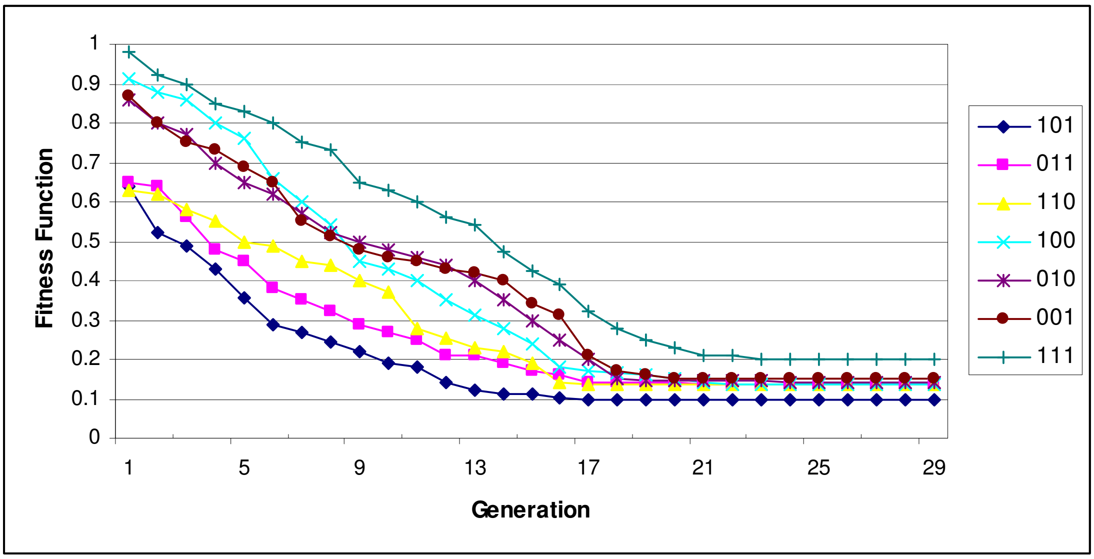

Figure 4. The fitness function amount in each generation.

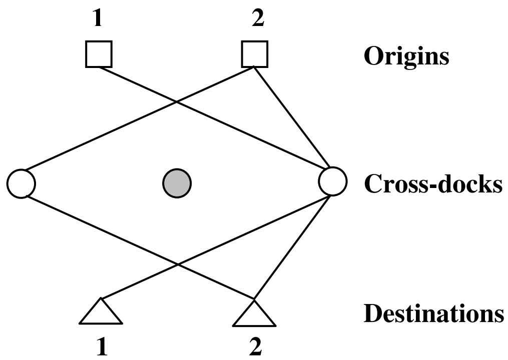

Figure 5. The best answer.

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The tactical stage solutions were made based on the results of the strategic stage. In the tactical phase, the internal relations and functions of the cross-docks were simulated by queues and distribution stocks. Usually in cross-docks, each shipping door is dedicated to one destination and each origin sends its deliveries to a specific receiving door. The receiving doors were simulated with parallel queues, each receiving goods from a specific origin point and the shipping doors were simulated with stock points, receiving dedicated goods from related queues and sending them to a specific destination.

The two simulation strategies concern the inter-cross-dock prioroties for transporting orders from receiving doors to the shipping doors and also different assignment of the human resources in the shipping doors. The first strategy indicates that the nearest shipping doors and the overally smallest orders should be served first and the second one signifies that the biggest order and the farthest order should be sereved first [4].

Applying the strategies result in different delivery leadtimes, delays, queuing times, storage costs, facility usage and transportation costs. The utility of a startegy however, is decided based on the manegerial preferences in how to weight the time-saving or cost-descreasing goals. The results of simulation with the two strategies are compared in the Tables 3 and 4 and Figures 7 and 8.

The product delivery within the cross-dock is finished earlier by the first strategy and the receiving doors' finishing times is ealier.

By implementing the second strategy the lift truck waiting time will increase. Since all the lift trucks from different origins aim to serve a shipping door first by their large deliveries over a long period of time, their waiting time will increase. The lift trucks busy time is higher by the first strategy.

The busy period of the personnel and facilities in the shipping doors seem to improve by the first strategy. The low busy period of the node I in the second strategy is due to node's waiting time for finishing the node II deliveries.

7. Conclusion

A multi objective nonlinear location allocation model is presented in this study to determine the cross-docks' location, their capacities and the products' routing through the system in the strategic stage. The model is simulated for comparing scheduling strategies in the tactical stage. Compared to previous literature on cross-docking location allocation problems and supply chain facility location problems, the proposed method has distinctive features:

1) The quantitative and qualitative objective functions of the model include the necessary features concerning cross docking systems and supply chain management.
2) The model suggests the best capacity for each product for the cross docks which was not considered in the cross docking models.
3) The internal cross-dock layouts can also be designed. The model can be further expanded to include the shape of the cross-docks and their centrality. It can be either the matter of choosing between different cross-docks in different shapes or deciding the shape of the cross-dock to be constructed.
4) Regarding the AHP weights, the problem shows to be more sensitive to the transportation costs, driven roads quality and construction costs.
5) The trucks are considered exclusively for each destination and each origin. The availability of the trucks can also be included in the model by usage of 0-1 variables indicating the assignment of the trucks to the tasks. However, entering a non-strategic decision into a strategic model is not suitable. The truck assignment problem can better be handled in the tactical stage.
6) Some deliveries may not require cross-docking functions and a vehicle may be able to be sent directly from origin to the destination without passing through the cross-dock. The direct deliveries from origins to the destinations can be considered by defining necessary variables.

[4] The total number of the required goods consider the size of an order.

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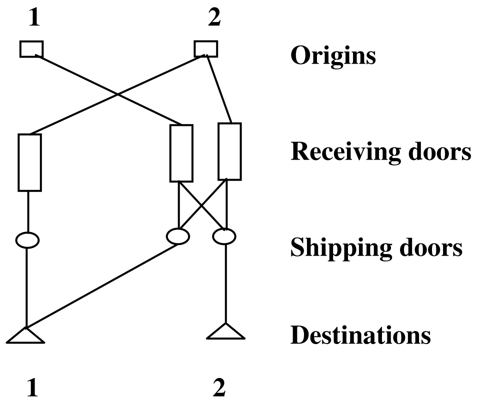

Figure 6. Receiving and shipping activities.

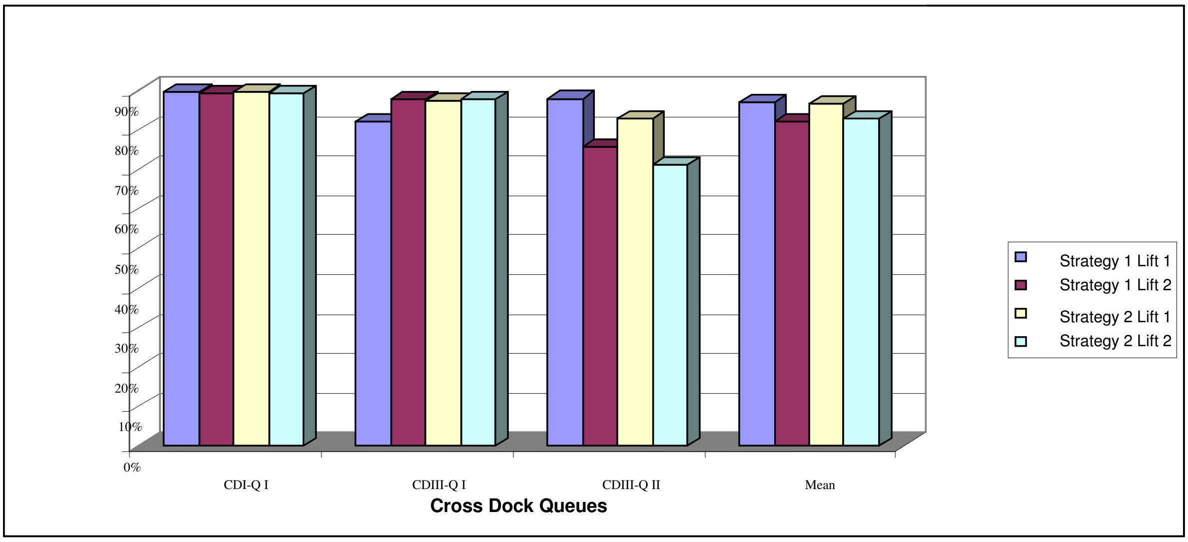

Figure 7. Lift trucks busy period.

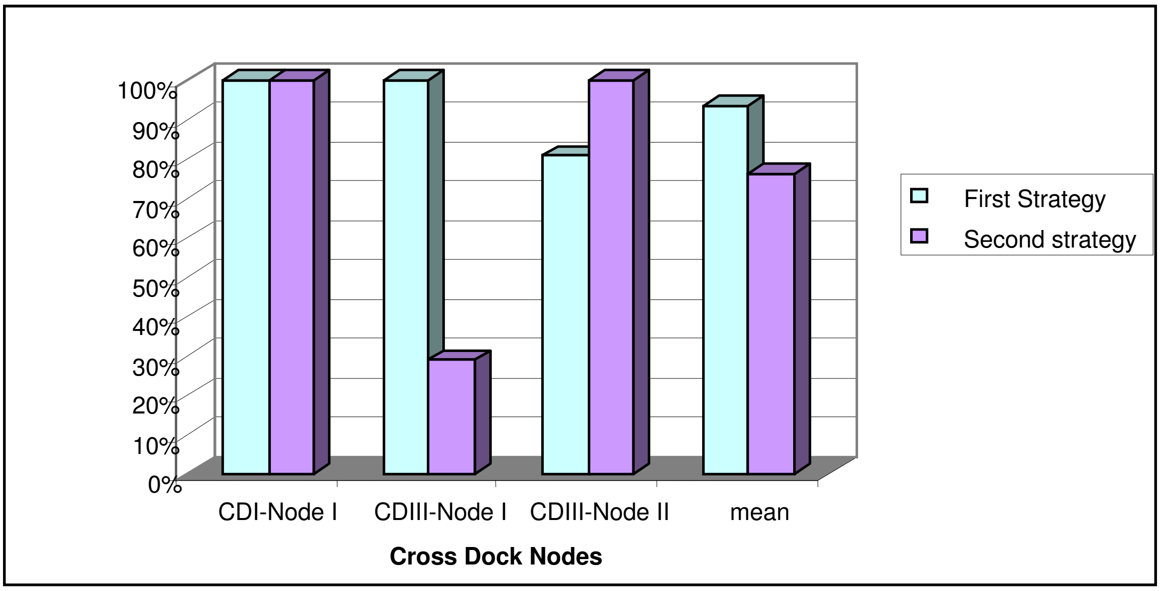

Figure 8. Cross dock nodes busy period.

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Table 3. Personnel and facilities' function in the queues.

		Queue	Starting Time	Finishing Time (min)	Lift truck I Idle time (min)	Lift truck II Idle time (min)	Lift truck I Busy period	Lift truck II Busy period
First Strategy	Cross-dock I	Q I	0	151.33	16	16.33	89%	89%
	Cross-dock III	Q I	0	125.58	22.75	15.67	82%	88%
		Q II	0	268.25	32.58	65.67	88%	76%
	Mean		0	181.72	23.78	32.56	87%	82%
Second Strategy	Cross-dock I	Q I	0	151.33	16	16.3	89%	89%
	Cross-dock III	Q I	0	125.58	15.9	15.6	87%	88%
		Q II	0	283.57	48.5	81.8	83%	71%
	Mean		0	186.83	26.80	37.90	87%	83%

Table 4. Personnel and facilities' function in the nodes.

		Queue	Start Time	Finishing Time	Idle time	Busy period
First Strategy	Cross-dock I	Node I	33.67	168	0	100%
	Cross-dock III	Node I	34.07	217.42	0	100%
		Node II	17.25	285.07	51.07	81%
	Mean		28.33	223.50	17.02	94%
Second Strategy	Cross-dock I	Node I	33.67	168	0	100%
	Cross-dock III	Node I	16.92	180.25	116.33	29%
		Node II	33.57	250.25	0	100%
	Mean		28.05	199.50	38.78	76%

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8. Suggestions for further researches

- The probabilistic parameters such as orders, delivering times, productions and etc. can also be considered. The usage of uncertain parameters results a more realistic model.
- In a cross-docking system, we should be able to switch between cross-docks when facing a problem. The possibility of having spare cross-docks, the costs, the risks and benefits can be studied.
- The decision variables that decide on the shape of the cross-docks can also be included in the cross-docking modeling problem. Where regarding the required receiving and shipping doors and cross-docks' location and the relations with the origin and destination points, its desired shape be suggested by the model.
- The origins' productions are supposed to be ready to deliver. The origins' production constraints can also be included in the model. Moreover, extra and substitutions for resources can be predicted in order to be able to switch between suppliers when needed.
- Cross-docking system managing software can be designed for assigning resources to the tasks. The inter-cross-docks' tasks and functions can be prescheduled to make necessary decisions and avoid shortages.

References

[1] Amiri, A., 2005, Designing a distribution network in a supply chain system: Formulation and efficient solution procedure. *European Journal of Operational Research*, 171(2), 567-576.

[2] Apaiah, R. K., Hendrix, E. M. T., 2005, Design of a supply chain network for pea-based novel protein foods. *Journal of Food Engineering*, 70, 383–391.

[3] Asgharpour, M. J., 2002, *Multiple Criteria Decision Making*. Tehran University Publications.

[4] Bartholdi, J. and Gue, K. R., 2003, The Best shape for a Crossdock. available at: http://www.scivis.nps.navy.mil/~krgue/Publications/shape-accepted.pdf .

[5] Bermudez, R. and Cole, M. H., A genetic algorithm approach to door assignment in breakbulk terminals. available at: http://ntl.bts.gov/lib/200207/15cb008.doc .

[6] Bremant, C., 2000, Cross-docking, How to use the EAN/UCC standards. *EAN International*, available at: http://www.eannet-france.org/fille/k/kb/kb4.htm.

[7] Chen, P., Guo, Y., Lim, A. and Rodrigues, B., 2006, Multiple cross-docks with inventory and time windows. *Computers and Operations Research*, 33(1), 43-63.

[8] Eben-Chaime, M., Mehrez A. and Markovich G., 2002, Capacitated location-allocation problems on a line. *Computers & Operations Research*, 29(5), 459-470.

[9] Eskigun, E., Uzsoy, R., Preckel, P. V., Beaujon, G., Krishnan, S. and Tew, J. D., 2005, Outbound supply chain network design with mode selection, lead times and capacitated vehicle distribution centers. *European Journal of Operations Research*, 165(1), 182-206.

[10] Gen, M. and Cheng, R., 1996, *Genetic Algorithms and Engineering Design*. John Wiley & Sons.

[11] Gue, R. K. and Kang K., Staging queues in material handling and transportation systems. available at: http://www.informssim.org/wsc01papers/149.PDF.

[12] Hugo A. and Pistikopoulos, E. N., 2005, Environmentally conscious long-range planning and design of supply chain networks. *Journal of Cleaner Production*, 13(15), 1471-1491.

[13] Jayarama, V. and Ross, A., 2003, "A simulated annealing methodology to distribution network design and management. *European Journal of Operational Research*, 144(3), 629-645.

[14] Klose, A. and Drexl, A., 2005, Facility location models for distribution system design. *European Journal of Operational Research*, 162(1), 4-29.

[15] Kurina, S. and Johnston, R. B., 1999, *The Mutuality of ECR Benefits, Costs and Risks in Supply Chain Reform.* Proceedings of the 3rd Collaborative Electronic Commerce Technology and Research, Wellington, New Zeland.

[16] Lemoine, O. W., 2004, Reconfiguration of supply chains and implications for transport: A Danish study. *International Journal of Physical Distribution & Logistics Management*, 34(10), 793-810.

[17] Ma, H. and Davidrajuh, R., 2005, An iterative approach for distribution chain design in agile virtual environment. *Industrial Management & Data Systems*, 105(6), 815-834.

[18] Melo, M. T., Nickel S. and Saldanha da Gama, F., 2005, Dynamic multi-commodity capacitated facility location: A mathematical modeling

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framework for strategic supply chain planning. *Computers & Operations Research*, 33(1), 181-208.
[19] Murty, K. G., Liu, J., Wan, Y. and Linn, R., 2005, A decision support system for operations in a container terminal. *Decision Support Systems,* 39(3), 309-332.
[20] Ratliff, H. D., Donadlson, H., Johnson, E. and Zhang, M., Schedule-driven cross-docking network. available at: http://www.isye.gatech.edu/research/files/misc9904.pdf .
[21] Ratliff, H. D., Vate, J. V. and Zang, M., Network design for load-driven cross-docking system. available at: http://www.isye.gatech.edu/research/ files/misc9914.pdf .
[22] Saaty, T. L., 1980, *The Analytic Hierarchy Process*. McGraw-Hill Co., NY.
[23] Saaty, T. L., 1990, How to make a decision: The analytic hierarchy process. *European Journal of Operations Research*, 48(1), 9-26.
[24] Simchi-Levi, D. and Kaminsky, P., 2003, *Designing and Managing the Supply Chain, Concepts, Strategies, and Case Studies*. McGraw-Hill Higher Education.
[25] Sheu, J., 2003, Locating manufacturing and distribution centers: an integrated supply chain-based spatial interaction approach. *Transportation Research Part E*, 39(5), 381-397.
[26] Waller M. A., Cassady, C. R. and Ozment, J., Impact of cross-docking on inventory in a decentralized retail supply chain. *Transportation Research Part E,* Paper in press.
[27] Yagiura, M., Ibaraki, T. and Glover, F., 2006, A path relinking approach with ejection chains for the generalized assignment problem. *European Journal of Operational Research*, 169(2), 548–569.

Appendix I: The basic model of Andreas Klose and Andreas Drexl

The capacitated facility location problem by Andreas Klose and Andreas Drexel [14], is as follows:

$$V(CFLP) = Min \sum_{k\in K}\sum_{j\in J} c_{kj} z_{kj} + \sum_{j\in J} f_j y_j$$

Subject to:

$$\sum_{j\in J} z_{kj} = 1 \qquad \forall k \in K \qquad (1)$$

$$\sum_{k\in K} d_k z_{kj} - s_j y_j \le 0 \qquad \forall j \in J \qquad (2)$$

$$z_{kj} - y_j \le 0 \qquad \forall j \in J, \forall k \in K \qquad (3)$$

$$\sum_{j\in J} s_j y_j \ge d(K) \qquad (4)$$

$$\sum_{j\in J_q} z_{lk} \le 1 \qquad \forall k \in K, \forall q \in Q \qquad (5)$$

$$0 \le z_{kj} \le 1 \qquad \forall j \in J, \forall k \in K \qquad (6)$$

$$0 \le y_j \le 1 \qquad \forall j \in J, \forall k \in K \qquad (7)$$

$$y_j \in \{0,1\} \qquad \forall j \in J\,. \qquad (8)$$

where K is the set of the nodes and $J \subseteq K$ denotes the set of potential facilities.

$z_{kj} = 1$ if the demand point k is assigned to the cross-dock j and 0 otherwise.

$y_j = 1$ if the node j is chosen as a cross-dock and 0 otherwise.

s_j indicates the maximum capacity of the node j.

d_k indicates the demand of the node k.

f_j represents the fixed cost for opening/operating the node j.

c_{kj} defines the variable cost.

Appendix II: Weighting the objectives by AHP

The Analytical Hierarchy Process Model was designed by T. L. Saaty as a decision making aid. By reducing complex decisions to a series of one-on-one comparisons, then synthesizing the results, AHP not only helps decision makers arrive at the best decision, but also provides a clear rationale that it is the best. AHP was developed in the 1970's by Dr. Thomas Saaty[5].

AHP is especially suitable for complex decisions, which involve the comparison of decision elements, which are difficult to quantify. It is based on the as-

[5] http://www.expertchoice.com/customerservice/ahp.htm

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sumption that when faced with a complex decision the natural human reaction is to cluster the decision elements according to their common characteristics [3,22].

It involves building a hierarchy (ranking) of decision elements and then making comparisons between each possible pair in each cluster (as a matrix). This gives a weighting for each element within a cluster (or level of the hierarchy) and also a consistency ratio [23]. The necessary pair-wise comparisons of all the elements in each level relative to each element in the higher level were established. The final results, shown in the table1, indicate the weight of the objective function. The hierarchy relations of the objective functions are shown in the Figure 9.

Appendix III: Alternative options for the model

1. The production capacity of the origin **o** is assumed to be more than the destination demand. If the demands were more than the provided amount of products, the unsatisfied demand for the product of the origin *o* in the destination *k* is equal to:

$$ud_{ko} = d_{ko} - \sum_{j\in J} l_{jok}$$

2. Since the demand in the destination is never less than the transshipped product, the sum above is weather a positive amount or is equal to zero.

3. If the number of the selected facilities should be equal to a desired amount of *N*, or should range between N_L and N_U, the following constraints can also be considered in the model:

$$\sum_{j\in J} y_j = N$$

$$N_L \le \sum_{j\in J} y_j \le N_U$$

4. The cross-dock capacity for a product implies the existence of the required material handling facilities and personnel in the cross-dock. The variable P_{jo} indicates the capacity (and implies its ability) of the cross-dock *j* for handling the products of the origin *o*.

Table 5. The objective functions' weights by AHP.

f_1	f_2	f_3	f_4	f_5	f_6
The traveled distance	Quality of the roads	Cost of per unit of capacity	Accessibility to infrastructures	Material handling costs	Fixed construction costs
0.265	0.23	0.15	0.205	0.045	0.105

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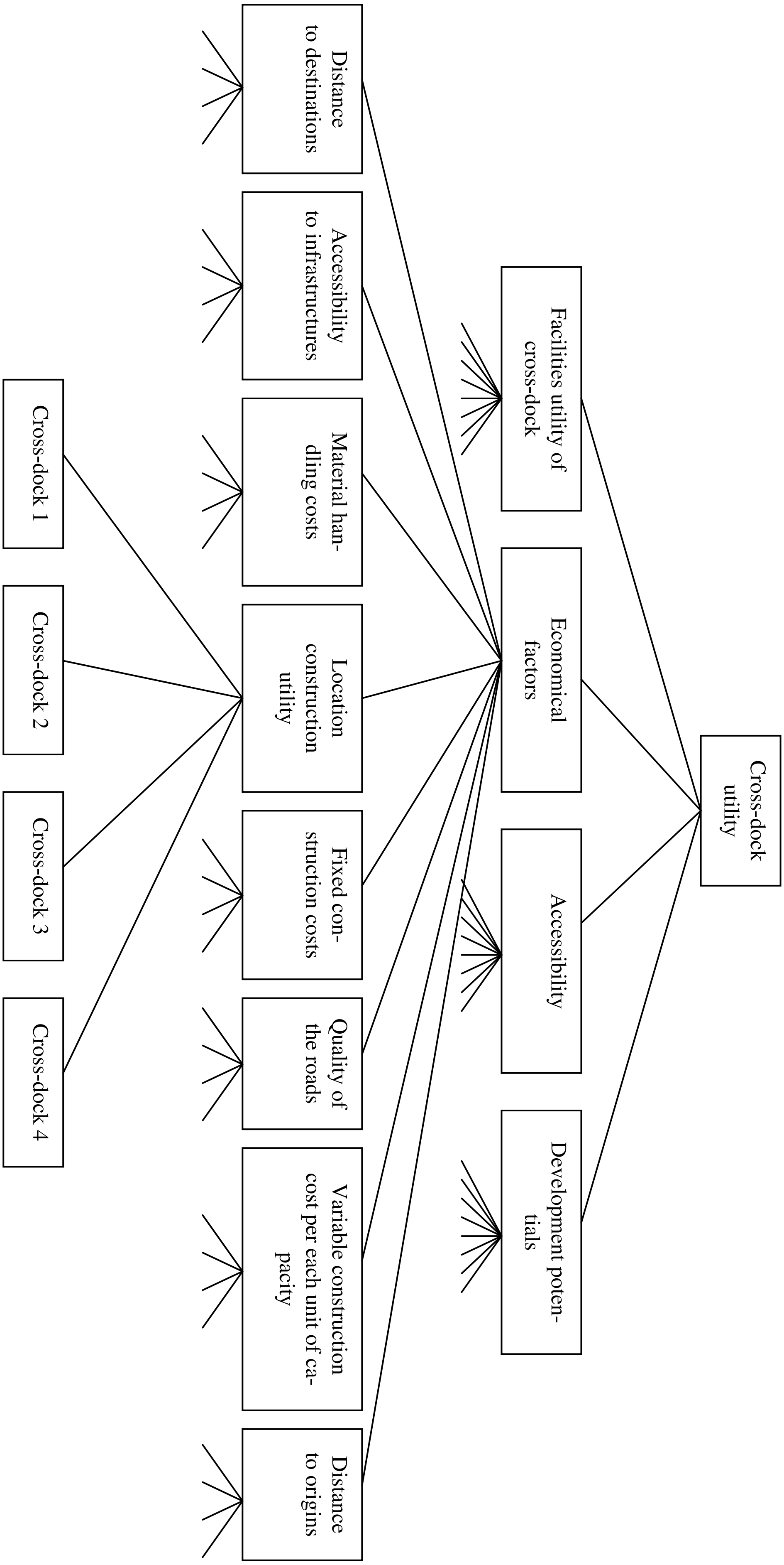

Figure 9. Hierarchy relations of the objective functions.

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