Customer service based design of the supply chain

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Abstract

The purpose of this study is to propose a framework by which service elements and a company’s own strategies can be included in the “traditional”, cost-based design of the supply chain. The framework is demonstrated with a numerical example and it is based on integrating the analytic hierarchy process (AHP) and mixed integer programming (MIP). The target is to optimise a company’s supply chain based on customer service requirements within the constraints of the supply chain. © 2001 Elsevier Science B.V. All rights reserved.

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1. Introduction

Supply chain design has been an important part of the logistics decision-making process in companies. The importance of supply chain design has increased when more and more companies have realised the possibilities of gaining additional value for their customers by restructuring the supply chain. In fact, the growing awareness of the critical impact of supply chain management on an organisation’s competitiveness, profitability and strategic advantage has made supply chain a truly strategic issue and it has received increased emphasis everywhere [1,2]. In addition, transportation as a part of logistics operations can be seen as a value-adding process that directly supports the primary goal of the organisation, which is to be competitive in terms of high-level customer service, competitive price and quality, and flexibility in responding to market demands [3]. The focus of logistics is increasingly turning towards providing better services for customers instead of minimising the total transportation or logistics costs or maximising the total profits of the supplier. Furthermore, logistics managers put more emphasis on controlling the whole logistics chain than concentrating on the problems of one echelon in the logistics process. One result of this is that there has been a growing interest on partnership and customer satisfaction issues. Firms are moving from a decoupled decision making process towards a more coordinated and integrated design and control of their supply chain to provide goods and services to the customer at low cost and high service levels [4]. Companies must also be able to efficiently respond to changes and reconfigure their resources to be able to
compete and create profit by taking advantage of the opportunities occurring in the market place [5].

Historically, the three fundamental stages of the supply chain, procurement, production and distribution, have been managed independently and buffered by large inventories [4]. This policy has changed, especially manufacturers have increasingly given their attention to the management of logistics issues, in the pursuit of strategies that will give them competitive advantage [6]. It is a well-known fact, that it is possible to gain even more advantage by improving the logistics chain instead of improving the performance of one player in the chain. Therefore, the area of logistics research is nowadays not solely restricted to the production process itself but has spread into a wide range of subjects relating to the entire material flow into, within, and out of the organization [7].

Section 2 discusses the different approaches to the distribution network design problem. In Section 3, we present an approach to customer service-based design of the supply chain which is based on the integrated utilisation of the analytic hierarchy process and mixed integer linear programming.

2. Logistics network design problem

The design of logistics network structure is an essential part of the location problem, which also is a well-known mathematical problem. One of the first theoretically oriented and widely quoted location problem papers was written by Hakimi [8]. After him, according to Hakimi and Kuo [9] it was Geoffrion and Graves, who first included production in the facility location models. These models are called capacitated production location problems. The first location–production–allocation problem with price-sensitive demands was given by Wagner and Falkson [10] (see also [11]). Since then several topics have been added to this base locating theory. The basic case is that facilities are to be established to meet fixed market demand by minimising the total cost of location, operation and transportation [9,11].

There are also many papers that deal with the plant location theory (see e.g. Verter and Dincer [12]). This paper presents the standard division of the plant location models:

- simple plant location problem (SPLP)
- plant location under uncertainty (SPLPU)
- international plant location problem (IPLP)

SPLP provides two types of decisions simultaneously [12] locational and allocations decisions. The SPLP model simply satisfies the market demands with minimal costs. According to Sridharan [13] the SPLP problem can also be called uncapacitated plant location problem when each potential plant does not have an upper bound capacity on the amount of demand that it can serve. The SPLPU problem has a profit maximization objective, and the IPLP problem is stochastic in nature due to randomness in price and exchange range movements.

The most traditional quantitative framework for distribution network design is the cost minimisation approach, see for example, [11,14,15]. According to Lee [11] these models simultaneously locate a set of facilities and satisfy the demands of a given set of customers to minimise the total cost of location, operation and transportation. However, the problem of the cost minimisation framework is that it focuses the problem on the deliverer’s point of view, and excludes the profitability to the customers. The focus of a more advanced distribution network design framework is on profit maximisation, see for example, Hakimi and Kuo [9]. In the profit maximisation framework the costs of the distribution network are deducted from the customer’s profits. No attention is paid to the customer’s wishes, however, and therefore, they are not satisfied. In several papers, for example, Meshkat and Ballou [16] and Canel and Khumawala [17], customer service elements have been included in the distribution design problem, in addition to cost and profit information. Typically this, the so-called service-sensitive framework, includes elements like product availability, delivery time requirements and delivery frequencies.

In this paper, we propose a customer service-based approach to distribution logistics network design. The more widely used approaches for logistics network design are the minimisation of costs and maximisation of profits whereas the proposed
3. A customer service-based approach to logistics network design

In the present paper the approach is based on integrating the analytic hierarchy process (AHP) and mixed integer linear programming (MIP). The AHP and linear programming have earlier been used together e.g. by Liberatore for selecting R&D projects [18], by Korhonen and Wallenius [19] for formulating a marketing strategy, by Gass [20] for large-scale personnel planning models, and by Olson et al. [21] for an export planning model for a developing country.

The AHP and linear programming have previously been used together for logistics network design by e.g. Korpela and Tuominen [22], Lehmusvaara et al. [23], Korpela et al. [24], and Korpela and Lehmusvaara [25]. However, the logistics network design problem is approached in the publications mentioned above either by analysing the overall logistics chain as a whole or by concentrating on just one node or link of the overall logistics network. In this paper, the aim is to present an integrated framework for the design problem, i.e. an approach which, firstly, enables a customer-oriented evaluation of each alternative link and node in the logistics network and, secondly, optimises the overall customer service capability of the network.

The proposed approach consists of five basic steps:

1. **Defining the problem:** The first step involves defining the decision problem by e.g. stating the objectives, and determining the scope of the problem in terms of e.g. alternative transportation modes and routes.

2. **Determining the strategic importance of the customers:** The second step involves analysing the strategic importance of the customers affected by the logistics network design process. As the design of the network is based on the customer service preferences of the customers, the strategic importance of the customers is an important input to the design process. The AHP -method is used for supporting this phase.

3. **Analysing the customers’ preferences for customer service:** The aim of the third step is to analyse the preferences that customers have for the different elements of customer service. Each customer evaluates separately the importance of the different service elements from their point of view, and the AHP is used for supporting this phase.

4. **Evaluating the alternative nodes and links in the logistics network:** The fourth phase in the approach involves evaluating the alternative nodes and links of the logistics network, such as the transportation routes, warehouse operators and hauliers. The evaluation is based on the preferences defined in the previous phase for the different customer service elements. For the links and nodes on which an individual customer might not have direct experience or knowledge, such as sea transportation routes, the preferences set by various customers are combined in order to create a uniform basis for evaluating the alternative nodes and links. The preferences are weighted by the strategic importance of the customers in the combination process to take into account the differences in the strategic importance of the customers. In our example, the actual evaluation of the alternative nodes and links is then carried out by the representatives of the supplying company. However, in the case of e.g. the hauliers delivering the products to the customers, the customers are usually able to evaluate the alternatives themselves, and then the customer-specific preferences are used instead of the combined ones. The AHP-method is used for supporting the evaluation, resulting in a preference priority for each alternative link and node.

5. **MIP-based optimisation:** The final phase in the proposed approach involves optimising the logistics network based on the priorities defined in the previous phase. As the priority that is defined for each alternative link and node represents the evaluated capability of fulfilling the customer service requirements, the objective function for the optimisation is to maximise the overall priority of the logistics network, subject to relevant constraints and restrictions.

The utilisation of the proposed approach is demonstrated with a numerical, illustrative example.
3.1. Defining the problem

The first step of the proposed approach involves defining the network design problem. In this illustrative example, the supplying company (corporation A) is redesigning its logistics structure for one of its main market areas. The basic composition of the logistics network is the following: (1) the products are transported first from the production plant to the port of loading from which sea transport is used to move the products to the port of destination located in the market area, (2) the products are stored in a warehouse in the port of destination, and (3) the final delivery of the products to the customers from the warehouse is carried out by using truck transportation. As illustrated in Fig. 1, corporation A has two production plants that can be used for producing the products for the customers in this market area, there are two alternative ports of loading, two alternative ports of destination, three alternative sea transportation services from each port of loading to each port of destination, three alternative warehouse operators for storing the products in both ports of destination, and three alternative lorry companies (hauliers) for the final deliveries. Three customers located in the market area in question are included in the network design process.

The logistics network design problem is to evaluate the alternative links and nodes based on the customer service preferences and then to optimise the customer service capability of the logistics network.

3.2. Analysing the strategic importance of customers

The second step in the proposed approach involves analysing the strategic importance of the customers for the corporation A. As the analysis of the strategic importance involves multiple criteria many of which are qualitative, the AHP method is used for supporting this step.

The AHP is a systematic procedure for representing the elements of any problem in the form of a hierarchy [26]. AHP can be described as a theory of measurement for dealing with quantifiable and intangible criteria [27]. AHP is based on three principles: decomposition, comparative judgements and the synthesis of priorities [28]. First, a complex, multicriteria problem is decomposed into a hierarchy where each level consists of a few manageable elements [29]. These elements are then divided into another set of elements. Second, a measurement methodology based on pairwise comparisons is used for deriving priorities for the elements. Third, the priorities of the elements are synthesised to calculate the overall priorities for the decision alternatives. A detailed description of the AHP method can be found e.g. in Saaty [30].
According to the principles of the AHP method, the first step in analysing the strategic importance of the customers involves defining the criteria on which the analysis will be based. In this example, the strategic importance of the customers is analysed based on the following criteria: (1) the long-term profitability potential for the company resulting from serving a certain customer, (2) the possibilities of establishing a partnership-type relationship with a customer, (3) the anticipated development of the volumes purchased by a certain customer compared to the preferred ‘optimal’ size of a customer, and (4) the long-term, financial viability of a customer.

As shown in Fig. 2, the overall goal for the analysis is located on the highest level of the hierarchy, and the criteria can be found on the second level. In a typical AHP-hierarchy, the actual decision alternatives are located on the lowest level of the hierarchy. In this example, however, the ratings-feature (see [31]) of the AHP-method and the corresponding Expert Choice-software is utilised, i.e. a set of ratings is located on the lowest level of the hierarchy. The ratings are qualitative descriptions of the characteristics of a customer with regard to a certain criterion. The customers are then analysed by using the ratings scales with respect to each criterion. The use of the ratings-feature enables the analysis of numerous customers and makes it easy to add new customers to the evaluation process at any time. Naturally, the ratings can be different for each criterion but in this illustrative example the same ratings scale is used for all the criteria.

The second step in using AHP is to derive priorities for each element in the hierarchy. The priorities are set by comparing each set of elements pairwise with respect to each of the elements on a higher level [29]. A verbal or a corresponding nine-point numerical scale can be used for the comparisons which can be based on objective, quantitative data or subjective, qualitative judgements. In a group setting, there are several ways of including the views and judgements of each person in the priority setting process including, e.g. (1) consensus, (2) vote or compromise, (3) geometric mean of the individuals’ judgements, and (4) separate models or players [32].

With the hierarchy illustrated in Fig. 2, the priority setting procedure is started by comparing the criteria pairwise with respect to the goal. The second step is to derive priorities to the ratings with respect to each evaluation criterion. In a classical weights and scores approach, the ratings would be given ordinal numbers, such as one for unsatisfactory and five for outstanding [31]. Forman et al. state that the classical approach violates the proper use of “scales of measurement” with the implicit and incorrect assumption that, for example, outstanding is five times better than unsatisfactory. The problem is avoided in the AHP-method by deriving the priorities to the ratings with regard to each criterion using pairwise comparisons. The overall priorities for the elements in the hierarchy are calculated by adding all the contributions of the elements in a level with respect to all the elements on the level above.

The priorities of the evaluation criteria are shown in Fig. 2. The profitability potential is the most important aspect of a customer's strategic importance with the priority of 0.470. The possibility of establishing a long-term partnership is also
Table 1
The strategic importance of the customers

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Total</th>
<th>Profitability</th>
<th>Partnership</th>
<th>Volume</th>
<th>Financial viability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer 1</td>
<td>0.605</td>
<td>OUTSTANDING</td>
<td>BLW AVERAGE</td>
<td>ABV AVERAGE</td>
<td>AVERAGE</td>
</tr>
<tr>
<td>Customer 2</td>
<td>0.627</td>
<td>ABV AVERAGE</td>
<td>OUTSTANDING</td>
<td>BLW AVERAGE</td>
<td>ABV AVERAGE</td>
</tr>
<tr>
<td>Customer 3</td>
<td>0.365</td>
<td>BLW AVERAGE</td>
<td>AVERAGE</td>
<td>AVERAGE</td>
<td>OUTSTANDING</td>
</tr>
</tbody>
</table>

a major factor with the importance priority of 0.279. Financial viability has the priority of 0.147 and volume development 0.104.

The strategic importance of customers is analysed by relating a rating and the corresponding priority to a customer with regard to each evaluation criterion. The ratings are assigned to the customers by using a software program called Expert Choice. The ratings module of the program makes it easy to enter and modify the evaluations. The results of the evaluation of the strategic importance of the customers are shown in Table 1. The column labelled TOTAL shows the overall strategic importance of the customers. Based on the analysis, customer 2 is the most important with the priority 0.627 whereas the priority of customer 1 is 0.605 and the priority of customer 3 is 0.365.

3.3. Analysing customers’ preferences for logistics service

The aim of the third phase in the proposed approach is to analyse the customers’ preferences for logistics service by using the AHP. These preferences then form the basis for evaluating the capabilities of the alternative logistics network links and nodes. Basically, each customer included in the analysis could define its own set of customer service elements to be included in the AHP-model. However, in this illustrative example, we assume that the same AHP-hierarchy is used for all customers.

Based on discussions with the customers, the representatives of corporation A structure an AHP-model for the customer service preference analysis. The elements to be included in the hierarchy are the following: (1) reliability concerning delivery time, (2) reliability concerning condition of products (no damage, etc.), (3) flexibility concerning urgent deliveries, (4) flexibility concerning capacity, (5) cost level, and (6) value-added services, such as EDI-links. These criteria represent the main aspects of service that the customers expect from their suppliers.

The next step is to derive priorities for the customer service elements. The representatives of each customer derive the priorities by using the standard AHP procedure. The AHP-hierarchy and an example of the priorities are shown in Fig. 3. As the outcome of this phase, the preferences set by each customer for the different elements of customer service are known.

3.4. Evaluating the alternative nodes and links

The objective of the fourth phase is to evaluate the capabilities of the alternative nodes and links based on the service preferences set by the customers. In this illustrative example, the following evaluations are carried out:

Sea transportation services: The representatives of corporation A use the combined service preferences of the customers as the basis for evaluating the capabilities of the alternative sea transportation services between the ports of loading and the ports of destination.

Warehouse operators (located in the ports of destination): Correspondingly, the representatives of corporation A evaluate the service capabilities of the third-party warehouse operators located at the ports of destination.

Hauliers: Supported by the representatives of corporation A, each customer evaluates the capabilities of the alternative hauliers that can be used for the final delivery of the products.
For the evaluation of the sea transportation services and the warehouse operators, the service preferences of the different customers are combined by utilising the strategic importance of the customers to calculate the weighted average of the priorities of the service elements. The combined preference priorities are calculated as follows: (1) the preference priority given by a certain customer to a certain service element is multiplied by the strategic importance of the customer in question, (2) the resulting weighted priorities are summed for each service element and their weighted average is calculated, and (3) the resulted combined priorities for the service elements are normalised so that their sum equals 1.

The ratings-feature of the AHP-method is used for the evaluation of the alternative sea transportation services. Thus, the following ratings scales are defined for the different service elements by the representatives of corporation A:

- **Reliability/time**: the variation from the schedule on a certain sea transportation route can be expected to be: < 5 hours, < 10 hours, < 15 hours, < 20 hours, or > 20 hours,
- **Reliability/condition of products**: the percentage of the products arriving undamaged at the port of destination can expected to be: over 99%, 95–99%, 90–95%, or below 90%,
- **Flexibility/urgent deliveries**: urgent deliveries can be arranged by using a certain sea transportation route with a prior notice before: < 12 hours, < 24 hours, < 2 days, or > 2 days,
- **Flexibility/capacity**: the capability of a certain sea transportation route to respond to changing capacity requirements is: outstanding, above average, average, below average, or unsatisfactory,
- **Cost level**: the cost level of a certain sea transportation route is: outstanding, above average, average, below average, or unsatisfactory,
- **Value-added services**: the capabilities of a sea transportation route to support the efforts to offer value-added services are: outstanding, above average, average, below average, or unsatisfactory.

In this illustrative example, it is assumed that the representatives of corporation A derive the priorities for the ratings. However, if possible, the customers could also be utilised for giving their preferences for the ratings. The complete hierarchy for the evaluation of the alternative sea transportation services is shown in Fig. 4.

The next step in the evaluation process is to assign a rating to each alternative sea transportation service with regard to each criterion. As mentioned in the problem definition phase, there are three alternative sea transportation services available from each port of loading to each port of destination, i.e., there are altogether 12 alternative services to be evaluated. For example, the service labelled 11A refers to the first of the alternative three services (A) between the first port of loading and the first port of destination (11). The results of this evaluation process are presented in Table 2. The column labelled TOTAL shows the final result of the sea transportation service evaluation, i.e., the priority for each route representing its capability to respond to the customer service requirements.

The evaluation of the alternative warehouse operators at the ports of destination is carried out correspondingly. The combined customer service preferences form the basis for the analysis, but the rating scales for the criteria are different from the ones used in the case of the sea transportation services. By using different ratings, the specific requirements for the different nodes and links can be included in the analysis. Thus, the proposed approach is flexible in allowing different interpretation of the customer service requirements for different links and nodes in the logistics network. Apart from the different ratings scales, the evaluation of the warehouse operators is carried out similarly to
Fig. 4. The AHP-hierarchy for evaluating the sea transportation services.

Table 2
The evaluation of the sea transportation services

<table>
<thead>
<tr>
<th>Services</th>
<th>Total</th>
<th>Real time</th>
<th>RELCOND</th>
<th>FLEURG</th>
<th>FLECAPA</th>
<th>Cost</th>
<th>VALADD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service 11A</td>
<td>0.554</td>
<td>&lt; 15 H</td>
<td>&gt; 99%</td>
<td>&lt; 12 H</td>
<td>AVERAGE</td>
<td>ABV</td>
<td>AVERAGE</td>
</tr>
<tr>
<td>Service 11B</td>
<td>0.660</td>
<td>&lt; 15 H</td>
<td>95-99%</td>
<td>&lt; 12 H</td>
<td>OUTSTAND</td>
<td>OUTSTAND</td>
<td>OUTSTAND</td>
</tr>
<tr>
<td>Service 11C</td>
<td>0.644</td>
<td>&lt; 15 H</td>
<td>&gt; 99%</td>
<td>&lt; 12 H</td>
<td>BLW</td>
<td>AVER</td>
<td>ABV</td>
</tr>
<tr>
<td>Service 12A</td>
<td>0.565</td>
<td>&lt; 10 H</td>
<td>&gt; 99%</td>
<td>&lt; 24 H</td>
<td>AVERAGE</td>
<td>ABV</td>
<td>AVERAGE</td>
</tr>
<tr>
<td>Service 12B</td>
<td>0.567</td>
<td>&lt; 5 H</td>
<td>95-99%</td>
<td>&lt; 2 D</td>
<td>BLW</td>
<td>AVER</td>
<td>AVERAGE</td>
</tr>
<tr>
<td>Service 12c</td>
<td>0.579</td>
<td>&lt; 10 H</td>
<td>90-96%</td>
<td>&gt; 2 D</td>
<td>OUTSTAND</td>
<td>OUTSTAND</td>
<td>OUTSTAND</td>
</tr>
<tr>
<td>Service 21A</td>
<td>0.666</td>
<td>&lt; 10 H</td>
<td>99%</td>
<td>&lt; 24 H</td>
<td>OUTSTAND</td>
<td>OUTSTAND</td>
<td>AVERAGE</td>
</tr>
<tr>
<td>Service 21B</td>
<td>0.471</td>
<td>&lt; 15 H</td>
<td>90-95%</td>
<td>&lt; 12 H</td>
<td>ABV</td>
<td>OUTSTAND</td>
<td>AVERAGE</td>
</tr>
<tr>
<td>Service 21C</td>
<td>0.566</td>
<td>&lt; 10 H</td>
<td>90-95%</td>
<td>&lt; 2 D</td>
<td>ABV</td>
<td>OUTSTAND</td>
<td>OUTSTAND</td>
</tr>
<tr>
<td>Service 22A</td>
<td>0.575</td>
<td>&lt; 5 H</td>
<td>95-90%</td>
<td>&lt; 2 D</td>
<td>AVERAGE</td>
<td>BLW</td>
<td>BLW</td>
</tr>
<tr>
<td>Service 22B</td>
<td>0.633</td>
<td>&lt; 5 H</td>
<td>90-95%</td>
<td>&lt; 24 H</td>
<td>BLW</td>
<td>BLW</td>
<td>ABV</td>
</tr>
<tr>
<td>Service 22C</td>
<td>0.648</td>
<td>&lt; 15 H</td>
<td>&lt; 99%</td>
<td>&lt; 12 H</td>
<td>OUTSTAND</td>
<td>ABV</td>
<td>ABV</td>
</tr>
</tbody>
</table>

the sea transportation service analysis, and thus only the final priorities for the warehouse operators are shown in Table 3.

In this illustrative example, the customers themselves, although supported by the representatives of corporation A, evaluate the service capabilities of the alternative hauliers. As the hauliers are in direct contact with the customers while delivering the products from the warehouses to the customers, it is assumed that the customers have enough knowledge and insight for analysing the hauliers. Basically, the procedure for the haulier evaluation is similar to the two previous evaluations: first, a certain customer uses the AHP-hierarchy and the priorities that it has defined to define the ratings scales and their priorities, and second, the customer assigns a rating for each alternative haulier regarding each customer service element. The outcome of these evaluations is a customer-specific priority for each alternative haulier, i.e., each customer has defined the preference order of the hauliers. The preference priorities set by the customers for the hauliers are presented in Table 4.

To summarise, the AHP-based evaluation results in priorities for the alternative nodes and links in the logistics network. Instead of costs, these priorities are then used in the next phase as the input of the MIP-model in order to define the logistics network that most effectively responds to the customer service requirements subject to the relevant restrictions.
Table 3
The priorities of the alternative warehouse operators

<table>
<thead>
<tr>
<th>Port of destination 1</th>
<th>Port of destination 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warehouse operator 1</td>
<td>0.68</td>
</tr>
<tr>
<td>Warehouse operator 2</td>
<td>0.77</td>
</tr>
<tr>
<td>Warehouse operator 3</td>
<td>0.76</td>
</tr>
<tr>
<td>Warehouse operator 4</td>
<td>0.54</td>
</tr>
<tr>
<td>Warehouse operator 5</td>
<td>0.58</td>
</tr>
<tr>
<td>Warehouse operator 6</td>
<td>0.78</td>
</tr>
</tbody>
</table>

Table 4
The preference priorities of the hauliers

<table>
<thead>
<tr>
<th>Customer 1</th>
<th></th>
<th>Customer 2</th>
<th></th>
<th>Customer 3</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Haulier</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Port of destination 1</td>
<td>0.66</td>
<td>0.74</td>
<td>0.72</td>
<td>0.68</td>
<td>0.71</td>
</tr>
<tr>
<td>Port of destination 2</td>
<td>0.73</td>
<td>0.48</td>
<td>0.51</td>
<td>0.78</td>
<td>0.79</td>
</tr>
</tbody>
</table>

3.5. MIP-based optimisation of the logistics network

The aim of the MIP-based optimisation is to evaluate the logistics network by maximising the AHP priorities within the existing physical restrictions in the distribution network. The problem definition for corporation A is given in Section 3.1, and the logistics network of corporation A is shown in Fig. 1.

To demonstrate the use of the present approach two illustrative cases have been prepared. These cases are:

Case 1: A preference maximisation case excluding the strategic decisions of corporation A

Case 2: A preference maximisation case including the strategic decisions of corporation A.

In both cases the objective function and the physical restrictions of the logistics network are the same, but in case 2 the corporation A has made three strategic decisions. The first decision is to give an upper limit for the number of hauliers delivering the products to final customers. The second strategic decision in case 2 is to give a minimum required volume for each haulier to be reached before it can be selected. The third strategic decision is to limit the number of sea operators between the ports of loading and destination. These three strategic decisions have been made, because it has been decided to keep the number of service providers at the minimum, and because these decisions will ensure that the volumes of the hauliers will be big enough to guarantee acceptable operation level for the service providers. These strategic decisions are given to the MIP model by introducing 0/1 variables and the needed restrictions. The most important stages in the logistics network for corporation A in regard to the overall customer service provided to the final customers are sea transportation, warehousing in the ports of destination and final transportation to the customers. Therefore, these stages have been included in the objective value of the problem. In the AHP process preferences have been given to these stages, which have the major role in forming the final customers’ service level.

The objective value for the MIP-based preference maximisation model is defined as follows:

\[
\text{MAX } Z = \sum_{p=1}^{P} \sum_{l=1}^{L} \sum_{d=1}^{D} PS_{pld} V_{S_{pld}}
\]
Table 5
The differences between cases 1 and 2

<table>
<thead>
<tr>
<th>Port of destination d1</th>
<th>Customer c1</th>
<th>Customer c2</th>
<th>Customer c3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1</td>
<td>Haulier</td>
<td>Haulier</td>
<td>Haulier</td>
</tr>
<tr>
<td></td>
<td>h1</td>
<td>h2</td>
<td>h3</td>
</tr>
<tr>
<td></td>
<td>68 000</td>
<td>22 000</td>
<td></td>
</tr>
<tr>
<td>Case 2</td>
<td></td>
<td></td>
<td>128 000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Port of destination d2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Case 1</td>
<td></td>
<td></td>
<td>55 000</td>
</tr>
<tr>
<td>Case 2</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>90 000</td>
<td></td>
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</tr>
</tbody>
</table>

In both cases market demand is identical and is shown in Table 5. In the first case no limits have been given to the required transportation volumes of the hauliers, whereas in the second case the upper limit for the transportation company per harbour was selected to be 150 000 tons and the maximum number of hauliers was forced to be two.

The volumes of production, ports of loading and destination as well as the volumes of warehouse operators remained the same in both cases. Instead, there were changes in the volumes of the hauliers. The results of cases 1 and 2 are shown in Table 5. From Table 5 we can see that in case 1 all the hauliers (h1, h2 and h3) are used. Table 5 also shows that in case 2 only two hauliers selected to take care of the customer deliveries. This change is caused by the upper limitation (maximum two) to the number of hauliers in case 2.

4. Conclusions

The main problems in the traditional approaches for logistics network design are that they focus on the deliverer’s point of view. Therefore, the traditional approaches concentrate on the objectives of one organisation in the supply chain and they normally exclude the strategic viewpoints of the deliverer.

The intention of the present approach is based on integrating the analytic hierarchy process and mixed integer programming to expand the scope of
the traditional approaches to a more customer oriented direction by implementing customers’ preferences on the decision process. In addition, the strategic viewpoints of the supplier, as well as the limitations and restrictions of the distribution network are included. The objective of the proposed approach is to provide a systematic and flexible framework for the customer service based design of the supply chain also taking into account the strategic decisions of the supplier.

The potential problem related to the AHP-phase of the approach is the availability of the required information. As there are several nodes and links to be evaluated, it might be difficult to gather all the required data concerning all activities and their preferences and costs. However, the AHP-analysis can be carried out based on inadequate data as the AHP-method supports the use of subjective judgements.

All assumptions and restrictions of linear programming (LP) and mixed integer programming (MIP) are faced, when a firm is implementing the approach. Therefore, it is important to be familiar with these assumptions and restrictions, which are well documented in the literature (see, for instance, [33]). In practise, the most significant restriction in the MIP-phase of the approach is the number of the 0/1 variables in the problem. These variables are needed for calculating the maximum number of see transport providers and hauliers as well as for counting the minimum required transportation volumes for truck carriers. The supply chain design is a strategic level problem, which means that the mathematical calculations for solving the problem are made e.g. annually. For this reason, there are enough time to carry out needed calculations for example during evenings or nighttime, which means that the number of the 0/1 variables is normally not limiting the use of the approach.

References