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ABSTRACT

This research study presents a comprehensive model for selection of decisive criteria to develop and integrate a fourth-party logistics concept in humanitarian logistics sector. The model is based on applying an analytic network process for determination of final criteria selection for a fourth-party logistics solution. The analytic network process is used to solve complex multiple qualitative and quantitative decision problems into a single overall score for ranking decision alternatives. Criteria appropriate for the selection of conditions relevant to the humanitarian logistics sector have been identified and will be the base to construct an analytic network process structure. This research enables a decision maker such as a commercial fourth-party logistics service provider to better understand the complex humanitarian logistics environment, enhance humanitarian logistics management and to develop new and accurate logistics solutions that are fit for the humanitarian logistics sector.

Keywords: Fourth-party humanitarian logistics, collaboration, analytic network process, efficiency, effective logistics processes
INTRODUCTION

In recent years, the topic of humanitarian logistics – and in particular collaboration in this sector – has become more popular because of the disastrous execution of logistics processes after the Indian Ocean tsunami in 2004. Problems encountered in such natural disasters are various: information and communication network systems are disrupted, access to roads is limited, infrastructure is destroyed, and equipment to remove destroyed buildings as well as other resources such as trained local officials and volunteers are not available. Disasters will continue to occur. Since 1975, the total number of natural and technological disasters has increased considerably. In 2010 385 natural disasters without consequences such as diseases and epidemics have hit 131 countries worldwide, affecting 217 million people, killing 297 thousand people and causing US$123.9 billion in damages (Guha-Sapir et al., 2011). Thomas and Kopczak expect a steady five-fold increase in the number of natural disasters over the next fifty years (Thomas and Kopczak, 2007). In order to overcome vulnerability and to battle the impact caused by natural disasters, an effective humanitarian logistics system has to be in place, whereby successful relief operations can be achieved. Therefore humanitarian logistics as well as emergency and humanitarian aid delivery have to be managed more efficiently.

Humanitarian logistics is here defined as “[…] the process of planning, implementing and controlling the cost-effective flow and storage of goods and materials, as well as related information, from the point of origin to the point of consumption for the purpose of alleviating the suffering of vulnerable people. The function encompasses a range of activities, including preparedness, planning, procurement, transport, warehousing, tracking, tracing and customs clearance” (Thomas and Kopczak, 2005). In brief, humanitarian logistics focuses on “…preparedness, planning, procurement, transport, warehousing, tracking and tracing and customs clearance” (Kovacz and Spens, 2007). This complex environment requires practical yet robust solutions that improve and promote process efficiency in logistics. The fourth party logistics concept may be such a solution. Therefore the focus of this research paper is the potential of positioning a fourth-party logistics concept as a network integrator in the humanitarian logistics sector. This concept argues for an effective management of logistics activities and enhances the collaboration between the actor of humanitarian logistics sector as well as coordination of humanitarian relief goods along the humanitarian supply chain.

Currently, fourth-party logistics concept and fourth-party logistics service providers exist in the commercial sector across different logistics industries. According to the work done regarding the differences between humanitarian logistics and commercial logistics, e.g. by Beamon 2004; van Wasschenhove 2006; Kovacz and Spens 2007; and Abidi and Klumpp 2011, the existing fourth-party logistics service provider of commercial logistics cannot simply be integrated into the humanitarian logistics sector because of the varying requirements, challenges and objectives. After an introduction, the paper is structured as follows. First, a generalized fourth-party logistics concept will be presented together with existing examples of fourth-party logistics in the humanitarian logistics sector. This is followed by presenting the specific problems related to the selection of criteria for humanitarian logistics solutions that can be offered by fourth-party logistics service provider to humanitarian organizations. We then present the analytic network process methodology as well as its solution. The last part of the paper is a discussion of the implications of these findings for the current and future state of the art in the field of humanitarian logistics.
FOURTH-PARTY LOGISTICS

In the commercial sector it is becoming more common that organizations aim to outsource their logistics activities like warehousing, transportation, ICT and customs clearance to fourth-party logistics (4PL) service provider. Companies may do this for several reasons, such as concentration on core competencies, cost reduction, development of supply partnerships, globalization and efficient processes. The most important driver is to win the expertise and experience of the logistics service provider. 4PL neutrally manages logistics processes and is characterized by outsourcing to a provider for effective management of logistics processes (Hingley et al., 2011). Fourth-party logistics (4PL) is established to support supply chain collaboration and to focus on vertical and horizontal integration. In addition, “4PL is treated as a strategic partner rather than a tactical one and is a supply chain integrator that synthesizes and manages the resources, capabilities, and technology of its own organization with those of complementary service providers to deliver a comprehensive supply chain solution” (Mukhopadhyay and Setaputra, 2006). By using 4PL services, companies aim to ensure transparency, process re-engineering, strategy development and improved management of resources across their supply chain and can concentrate on core competencies (Jensen, 2010; Hingley et al., 2011). A 4PL services provider acts to master and coordinate the assets of other supply chain members (Chopra and Meindl, 2010). Jensen 2010 and Christopher 2005 present four core competencies of a 4PL provider: system architecture and integrator, supply chain control room, supply chain information system and resource provider (Jensen, 2010; Christopher 2005). The humanitarian logistics sector seeks to enhance and improve coordination, to develop partnerships between humanitarian actors and to promote an effective and efficient logistics process during emergency response. We have identified three different initiatives that are often labeled as fourth-party logistics providers for the humanitarian logistics sector. These three will be discussed below.

The first are the Logistics Emergency Teams (LETs), which were launched in 2008 and consist of four companies from the logistics and transport industry: Agility, A.P. Moeller Maersk, UPS and TNT Express. These four companies, which are to a certain extent competitors in the commercial sector, act as one business unit in the humanitarian logistics sector (Cozzolino, 2012). They have different corporate social responsibility programs and are experienced in humanitarian relief operations. LETs assist the humanitarian logistics sector with emergency response logistics after an occurrence of a disaster. During the response phase LETs work with the World Food Programme (WFP as the global lead of the logistics cluster to offer the relief community logistics professionals, logistics knowledge and assets such as warehouses, trucks, forklifts and transportation services in the first three to six weeks after the occurrence of a disaster (logcluster, 2008).

<table>
<thead>
<tr>
<th>Company</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agility</td>
<td>Logistics knowledge and global network. Reconstruction and recovery efforts, transportation of food and medical aid as well as offering logistics consultancy (agilitylogistics, 2012).</td>
</tr>
<tr>
<td>A.P. Moeller Maersk</td>
<td>Risk assessment in the preparedness phase, in the response phase providing medicine, food and shelter. In the Reconstruction and recovery phase providing economic rehabilitation in the affected society (Maersk, 2012).</td>
</tr>
<tr>
<td>UPS</td>
<td>Transporting relief goods to affected countries, vetting in-kind donation, human resources, skills and knowledge, financial support, infrastructure and assets (UPS, 2012).</td>
</tr>
<tr>
<td>TNT Express</td>
<td>Support WFP in fighting the world hunger and optimizing the relief operations in sharing knowledge and skills, emergency response, advocacy and engagement, warehouse and transportation capacity (movingworld, 2012)</td>
</tr>
</tbody>
</table>

A second example is Sustain Global Partnerships (SUSTAIN GP), which has been formed in 2012 by two humanitarian organizations, World Vision and CARE, two leading logistics and transport provider (UPS and TNT), two financial and consultant organizations (Booz Allen Hamilton and Accenture) and IT specialists at Georgia Tech. SUSTAIN GP is a not-for-profit organization and a for-profit investment contract organization. SUSTAIN GP provides procurement, logistical support, network and innovative supply chain solution and technology for humanitarian organizations and for the humanitarian logistics sector. The concept of SUSTAIN GP is between that of a third-party logistics and fourth-party logistics provider.

![Figure 1: Structure of SUSTAIN GP](image)

SUSTAIN GP offers supply chain solutions for local and international humanitarian organizations with a focus on improving the last mile delivery, reducing costs by increased volumes, enhancing monitoring and tracking as well as logistics efficiency, innovation in technology, establishing supply chain management joint ventures, supporting transparency and accountability, avoiding competition between humanitarian organization in the field and gaining increased supply chain management capacities. Furthermore SUSTAIN GP offers long-term partnerships in supply chain management to humanitarian organizations based on a contract. The concept is currently piloted in Honduras where SUSTAIN GP is purchasing fuel for humanitarian organization and sells it to participating partners for 10- to 15% less than the market price. There is such a price difference because of consolidation of fragmented and small volumes and coordinated supply. SUSTAIN GP will expand the logistics business worldwide and offers further specific services for humanitarian organization that are established or work in the aid and development countries.

The third is the Logistics Cluster, which is one of the clusters of the UN. In 2005, the UN established nine (later eleven) collaborative platforms of humanitarian activity (referred to as “clusters”) to address the problem of coordination among agencies. The Logistics Cluster in fact started off as the UNJLC (United Nations Joint Logistics Center) in 1996 in response to East Zaire crisis (INSEAD, 2005). UNJLC has been dissolved and converted to the Logistics Cluster in 2005. It is located in Rome and takes a role as a humanitarian coordinator at field level to improve and promote partnerships between humanitarian actors in the area of providing warehousing and transport capacities with the objective to enhance overall
emergency response efficiency and effectiveness. The Logistics Cluster is responsible for coordination, information management, to supply training for corporate partners, to develop tools to improve capacity and to provide logistics service to ensure effective and efficient emergency response logistics. The Logistics Cluster facilitates the realization of groups of humanitarian organizations to improve logistics processes and activities in humanitarian response.

**APPREACH AND METHODOLOGY**

**Analytic Network Process**

In order to develop and integrate a fourth-party logistics concept in humanitarian logistics sector decisive criteria have to be identified. Multi-criteria decision analysis (MCDM) can support this. MCDM solves decision problems that include multiple and conflicting purposes (Arbel and Vargas, 1992). In the operations research discipline there is a variety of MCDM methods; a suitable method for this research is the analytic network process (Saaty, 1990; Saaty, 1996). This process was designed and shaped by Saaty in 1990 (Saaty, 1990) and has to be seen as an extension of the analytic hierarchy process (Saaty, 2004). The analytic network process provides a more generalized model (Saaty, 2005) than the analytic hierarchy process without making assumptions about the independence of the criteria at different levels of the hierarchy and also of the criteria within a level (Saaty, 2001; Mls and Gavalec, 2009). The analytic hierarchy process (Saaty, 1980) solves multiple criteria problems in a hierarchical structure. In contrast, the analytic network process solves multiple criteria problems as well, but in a network structure (Saaty, 2001; Meade and Sarkis, 1998; Sarkis, 2000; Sarkis and Sundarraj, 2002). This research method is a decision-supporting method that integrates qualitative and quantitative data for prioritizing alternatives when multiple criteria have to be considered or for evaluating complex multiple criteria alternatives (Saaty, 2001). Following this approach the next basic steps have to be taken in selecting decision criteria for developing the concept of fourth-party humanitarian logistics (4 PHL), (Saaty, 1996; Meade and Sarkis, 1998; Saaty, 2001; Thakkar et al., 2005; Shyur, 2006; Jharkharia and Shankar, 2007; Tsai et al., 2007; Peters, 2008; Peters and Zelewski, 2008; Sevkli et al., 2008):

1) The model and structure have to be designed and the problem has to be formulated; the analytic network process model and structure is based on a literature review and an expert interview regarding humanitarian logistics practices; the expert interview support has to be applied to classify the crucial criteria and to build the upper level of the analytic network process model; identification of clusters and nodes.

2) Paired comparison of each criterion by humanitarian logistics experts to determine the importance and relevance of the criteria in order to achieve the objective. For this comparison, a scale of 1–9 is applied to compare any two elements. 1 indicates equal importance whereas a 9 indicates overwhelming dominance. Within the comparison matrices, it is assumed that, for each component, it takes inner and outer interdependence.

3) A component in each hierarchy is able to use some or all components of the previous components as the basis for conducting the evaluating operation.

4) It is able to change the absolute and numerical scales into the ratio scale despite conducting the comparison assessment.

5) After conducting the paired comparison, it is possible to use the positive reciprocal matrices to handle the follow-up process.

6) The preference relations conform to the transitivity, i.e. A is better than B, B is better than C, then A is better than C, but also the useful step of components can be obtained by the weighting principle.

7) Every element that appeared in the hierarchical framework, whether or not its advantageous degree was small, will be regarded as relating to the whole evaluation framework but with the independent from a non-check hierarchical structure.

Application of Analytic Network Process and results
The required data for the analytic network process were collected by means of a questionnaire. Experts from humanitarian organizations, logistics providers and academia sector were asked to compare two elements with respect to a third inducing factor in the network using point scale to identify level of importance. 8 respondents have participated. All nine steps mentioned above and based on literature (Saaty, 2001; Saaty, 1996; Peters, Zelewski, 2008; Sevkli et al., 2008; Tsai et al., 2007; Shyur, 2006; Jharkharia, Shankar, 2007; Thakkar et al., 2005; Meade, Sarkis, 1998; Peters, 2008) were applied. The suggested model is built up by using a specialized software package (SuperDecision). The model consists of three clusters representing 19 nodes along with their outer dependencies and interdependencies as shown in figure 2:

1) In the proposed analytic network process model the problem has been formulated as follows: “to determine the decisive crucial criteria for integrating and developing fourth-party logistics concept into humanitarian logistics sector”. This includes goals such as long-term realtionship in humanitarian supply chain, different operational activities such as warehousing, transportation, quality management, network integrator, market share and financial performance. In addition to this, the important outcomes are cost, quality and reputation.

2) The criteria in the proposed analytic network process have been classified into three categories: goals, clusters and alternatives. The analytic network process model is structured in a) three goals: relationship which is important for partnership, coordination and collaboration, operational activities that support an effective logistics process and financial performance that is crucial for donors by recognizing reducing delivery costs and losses and ensure transparency and accountability. These three goals have interdependencies among themselves and are connected to clusters that support the achievement of the upper-level goals, b) the clusters encompass green logistics, performance measurement tool, information management, IT capacity, compatibility, network, georaphical location, quality management, delivery, damage quote, market share, flexibility in billing, payment and insurance management. The third level criteria c) alternatives: cost, quality and reputation support the clusters and have interdependencies among themselves. The graphical design of the analytic network process model is showed in step three.
3) Development of an ANP structure

![Diagram of ANP structure]

Figure 2: Analytic network process structure

4) This step entails the development of a pairwise comparison matrix: after the development of an analytic network process structure a pairwise comparison matrix can be established and formed using various judgments of clusters and alternatives by means of a questionnaire. The following figure shows a sample of the questionnaire modeled in the SuperDecision software. In the example the three clusters and 19 nodes were compared with each other with respect to influences on 4PL.

![Super Decision questionnaire]

Figure 3: Super Decision questionnaire

8 experts from humanitarian organizations, logistics providers and academia
sector were asked to compare two elements with respect to another inducing factor in the network using a scale of 1-9 (Saaty 2001) ranging from equal importance of both aspects (1) to high importance (9) of only one of the aspects. Furthermore the analytic network process can be used to derive relative weightings based on this measurement scale (Saaty 2001) as presented in the following table.

<table>
<thead>
<tr>
<th>Intensity of importance</th>
<th>Definition</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Equal importance</td>
<td>Two activities contribute equally to the objective</td>
</tr>
<tr>
<td>2</td>
<td>Weak</td>
<td>...between Equal and moderate</td>
</tr>
<tr>
<td>3</td>
<td>Moderate importance</td>
<td>Experience and judgment slightly favour one activity over another</td>
</tr>
<tr>
<td>4</td>
<td>Moderate plus</td>
<td>...between Moderate Strong</td>
</tr>
<tr>
<td>5</td>
<td>Strong importance</td>
<td>Experience and judgment strongly over another; its dominance demonstrated in practice</td>
</tr>
<tr>
<td>6</td>
<td>Strong plus</td>
<td>...between strong and very strong</td>
</tr>
<tr>
<td>7</td>
<td>Very strong</td>
<td>An activity is favoured very strongly over another; its dominance demonstrated in practice</td>
</tr>
<tr>
<td>8</td>
<td>Very, very strong</td>
<td>...between very strong and Extreme</td>
</tr>
<tr>
<td>9</td>
<td>Extreme importance</td>
<td>The evidence favouring one activity over another is of the highest possible order of affirmation</td>
</tr>
</tbody>
</table>

Table 2: Fundamental Scale for making judgment, Source: Saaty (2001)

5) This entails calculation of the eigenvector and eigenvalue of the comparison matrix from step 4: the maximum eigenvalue and eigenvector have to be calculated to estimate a relative weight of the decisive elements. The comparison matrix allows comparing the priority of elements.

Then the consistency value C.R. of the comparison matrix is calculated. C.R. supports by decision making, if the judgment and preferences of the experts has to be revised. The consistency value can be calculated as follows:

\[
\text{C.R.} = \frac{\text{CI}}{\text{R.I.}}
\]

(1)

In the denominator of Equation 1 \text{R.I.} presents a random index. This was randomly determined of a reciprocal matrix and is an average of a consistency index (CI is given by \(\lambda_{\text{max}} - n) / (n-1)\)). The values for a random index are fixed by Saaty (Saaty 2001) and can be adopted from following table.

<table>
<thead>
<tr>
<th>(n)</th>
<th>(R.I.)</th>
<th>(N)</th>
<th>(R.I.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0.00</td>
<td>9</td>
<td>1.45</td>
</tr>
<tr>
<td>3</td>
<td>0.52</td>
<td>10</td>
<td>1.49</td>
</tr>
<tr>
<td>4</td>
<td>0.89</td>
<td>11</td>
<td>1.51</td>
</tr>
<tr>
<td>5</td>
<td>1.11</td>
<td>12</td>
<td>1.54</td>
</tr>
<tr>
<td>6</td>
<td>1.25</td>
<td>13</td>
<td>1.56</td>
</tr>
<tr>
<td>7</td>
<td>1.35</td>
<td>14</td>
<td>1.57</td>
</tr>
<tr>
<td>8</td>
<td>1.40</td>
<td>15</td>
<td>1.58</td>
</tr>
</tbody>
</table>

Table 3: Random index table, sources: Saaty (2000); Saaty (2004)

When $C.R. \leq 0.1$ no correction of judgment and preferences is needed, that means the consistency is satisfied. Furthermore, the larger the inconsistency in the comparison matrix is, the larger is the value of consistency measure $C.R.$

6) Supermatrix formulation: By the application of the supermatrix, interdependencies that are among the elements of a system can be resolved. This is a subdivided matrix where each sub-matrix presents a set of relationships between and within the clusters or components in as system.

7) Weighted supermatrix formulation: the cumulative of the column vectors of a supermatrix, as can be noticed in table 4, is not equivalent to 1. A convergence has to be made for transforming in a weighted supermatrix. This explicit procedure ensures an adaptation of a long-term stable set of weights. That means the sum of each column has to be 1. The supermatrix has to be raised to the power $2^{k+1}$, where $k$ is an randomly large number and a weighted supermatrix is transformed. The following table illustrates the rating matrix. The rating of the elements after pair-wise-comparison can be obtained from the super matrix.

<table>
<thead>
<tr>
<th>Cluster/nodes</th>
<th>Cost</th>
<th>Quality</th>
<th>Reputaion</th>
<th>Financial performance</th>
<th>Operational activities</th>
<th>Relationship</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delivery</td>
<td>0.10057</td>
<td>0.22740</td>
<td>0.10449</td>
<td>0.14104</td>
<td>0.18047</td>
<td>0.17955</td>
</tr>
<tr>
<td>Experience in 4PL and HumLog</td>
<td>0.02988</td>
<td>0.05946</td>
<td>0.04299</td>
<td>0.0400</td>
<td>0.05153</td>
<td>0.05157</td>
</tr>
<tr>
<td>Flexibility</td>
<td>0.05235</td>
<td>0.00989</td>
<td>0.01140</td>
<td>0.02357</td>
<td>0.001581</td>
<td>0.01527</td>
</tr>
<tr>
<td>Geographical location</td>
<td>0.07503</td>
<td>0.08529</td>
<td>0.20221</td>
<td>0.12704</td>
<td>0.11282</td>
<td>0.11546</td>
</tr>
<tr>
<td>Green logistics</td>
<td>0.01225</td>
<td>0.02769</td>
<td>0.01172</td>
<td>0.01717</td>
<td>0.02197</td>
<td>0.02186</td>
</tr>
<tr>
<td>Information management</td>
<td>0.08103</td>
<td>0.05570</td>
<td>0.05060</td>
<td>0.04674</td>
<td>0.05246</td>
<td>0.05267</td>
</tr>
<tr>
<td>Insurance management</td>
<td>0.01656</td>
<td>0.00313</td>
<td>0.00361</td>
<td>0.00746</td>
<td>0.00500</td>
<td>0.00483</td>
</tr>
<tr>
<td>Market share</td>
<td>0.01218</td>
<td>0.01099</td>
<td>0.03500</td>
<td>0.02135</td>
<td>0.01757</td>
<td>0.01811</td>
</tr>
<tr>
<td>Network</td>
<td>0.08661</td>
<td>0.14960</td>
<td>0.15807</td>
<td>0.13341</td>
<td>0.14346</td>
<td>0.14449</td>
</tr>
<tr>
<td>Performance measurement</td>
<td>0.11975</td>
<td>0.02263</td>
<td>0.02608</td>
<td>0.05393</td>
<td>0.03617</td>
<td>0.03494</td>
</tr>
<tr>
<td>Quality management</td>
<td>0.12564</td>
<td>0.20524</td>
<td>0.24666</td>
<td>0.19659</td>
<td>0.20507</td>
<td>0.20703</td>
</tr>
<tr>
<td>Small damage quote</td>
<td>0.33814</td>
<td>0.14097</td>
<td>0.10418</td>
<td>0.18769</td>
<td>0.15765</td>
<td>0.15421</td>
</tr>
</tbody>
</table>

Table 4: Ratings weighted super matrix

8) Selection of the best alternative with a high impact on a supply chain. The most decisive criterion for 4PHL is quality with the highest ranking as shown in table 4, third column in: delivery, IT service, performance, warehouse, transportation, project management, location, experience, innovation and customer service. The rating of the alternative can be adapted from overall synthesized priorities which are presented in following figure. The preference values are in three different modes such as ideal, normal and raw. The raw values are directly adapted from the super matrix, ideal values are the raw values multiplied by the cluster weight and the normal values are obtained by normalizing ideal values as to sum up to 1. The results show that quality is the most important criteria for implementing fourth-party logistics concept and this can be seen as a benefit for the humanitarian logistics sector. The term “quality” in the variety of the logistics processes improves efficiency and increase the performance of the relief operations of the humanitarian organizations. Furthermore fourth-party logistics concept enhances

the collaboration between the humanitarian logistics actors by delivering information as well as services with high quality.

Figure 4: The preferences of alternatives

CONCLUSIONS

In this paper we described research on fourth-party humanitarian logistics using the Analytic network process. The approach and results present interesting insights and further challenges. The results demonstrate that there is a large potential in terms of increased coordination and efficiency. But on the other side problems may arise from transparency and trust questions e.g. about donors and image of the sector, demanding further research. A main challenge for fourth-party logistics service provider is which service has to be offered in which country and for which disaster. The approach gives an insight about the requirements of the humanitarian logistics sectors and their expectations related to the logistics concepts in particular fourth-party logistics. Further this approach offers to the fourth-party logistics service provider an opportunity to promote their current offered fourth-party logistics solution and to generate as well as create a new fourth-party logistics solution for humanitarian logistics sector and management by considering the subject quality management. Finally the paper present a further research like the theme Total Quality Management in humanitarian logistics sector which has to be investigated.

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