Multi-criteria supplier selection in the airline retail industry:
A real-world application at Netherlands’ major airline company

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Abstract

Since a company can merely perform as good as allowed by its suppliers, the extreme importance of supplier selection in supply chain management has been increasingly recognized. Supplier selection can be best described as a highly complex process due to the involvement of many, sometimes conflicting, both qualitative and quantitative criteria. The goal of supplier selection is to select the most suitable supplier(s) for meeting a company’s specific needs. This paper presents a case study on solving the supplier selection problem in the airline retail industry by means of a two-phased methodology. The first phase of the methodology employs a conjunctive screening method, which aims to reduce the initial set of potential suppliers prior to the comprehensive final choice phase. The second phase of the methodology employs a fuzzy AHP in which suppliers are evaluated against thirty-six sub-criteria. By means of combining the decision maker’s preferences and experts’ knowledge, the employment of the developed methodology will eventually result into a ranking of suppliers that enables to select the most suitable supplier(s). The paper concludes by proposing avenues for future research regarding the general applicability and further extensions.

Keywords: Airline industry, Conjunctive screening method, Fuzzy analytic hierarchy process, Retail, Supplier selection

1. Introduction

Whereas, in previous times, the airline industry could be characterized by high returns, high growth rates and governmentally regulated protectionism, nowadays, since the liberalization of the industry, the airline industry could be characterized best as a highly competitive market (Doganis, 2006). As a result, along with a loss in market share (Tretheway, 2004), the average yields of traditional airline companies have reduced (Teichert et al., 2008). To cope with the fierce competition and reduced profit margins, traditional airline companies seek to optimize operations within all aspects of their organization. The aspect of topic in this research is the airline retail branch. More specifically, this research addresses the issue of supplier selection of airline retail.

Retail can be characterized by intense pressure of competition, ever-changing customer requirements, and ever-changing product portfolios (Büyüközkan and Vardaloglu, 2012). Yusuf et al. (2004) argue that rapidly changing customer requirements force companies to develop agile supply chain capabilities to remain competitive. Hence, the supplier selection problem at hand can be defined as an agile supplier selection problem.

The objective of this research is to design a supplier selection methodology for Netherlands’ major airline to solve the agile supplier selection problem of airline retail. In addition, this research endeavors to add substance to the scientific body of knowledge in the following ways:

Firstly, since a vast majority of the current supplier selection literature focuses on supplier selection from a manufacturing perspective (e.g. Sarkis and Talluri, 2002; Kahraman et al., 2003; Choy et al., 2003; Chen et al., 2006; Huang and Keskar, 2007; Kahraman and Kaya, 2010), this research adds knowledge by providing insights into supplier selection from a retailer’s perspective. The fact that this is a real world case strengthens this argument.

Secondly, current supplier selection literature addresses various industries (e.g. automobile, pharmaceutical,
telecommunications, electronic). However, only one other scientific article by Chan et al. (2007) was found that applied supplier selection in the airline industry. Hence, this research will contribute to science by gaining insights from the application of a scientifically sound supplier selection methodology to the airline industry. Again, the fact that this is a real world case strengthens this argument.

Thirdly, although a number of fuzzy AHP applications for supplier selection can be found in the scientific literature (e.g. Kahraman et al., 2003; Chan and Kumar, 2007; Bottani and Rizzi, 2008; Kahraman and Kaya, 2010), the improved fuzzy AHP using FPP, developed by Rezaei et al. (2013), has not been applied yet to any supplier selection problem found in the literature. Thus, this research will contribute to science by means of applying a novel method to supplier selection.

Fourthly, although conceptual supplier selection models propose the application of multiple phases in supplier selection (e.g. De Boer et al., 2001; Luo et al.; 2009; Monczka et al., 2011), scientific literature lacks an actual application that applies more than one phase to a supplier selection problem.

The remainder of this paper is structured as follows: Section 2 will provide a literature review reflecting on supplier selection and appropriate methods. Section 3 explains the proposed two-phased supplier selection methodology into detail. Section 4 provides insights into the actual application of the developed methodology at the airline company. Section 5 discusses the obtained results. The paper ends with concluding remarks and avenues for future research in section 6.

2. Literature review

“The objective of supplier selection is to identify suppliers with the highest potential for meeting a firm’s needs consistently and at an acceptable cost” (Kahraman et al., 2003: p. 382). The general consensus in the scientific literature is that supplier selection is a task of extreme importance within purchasing and supply management (e.g. Dickson, 1966; Weber et al., 1991; Choi and Hartley, 1996; De Boer et al., 2001). Luo et al. (2009) identify three recent trends, which further emphasize the importance of the supplier selection. Firstly, due to the increased desire for outsourcing, firms spend a larger share of their revenues on externally sourced goods and services, which directly increases the impact of the supplier’s performance on buyers (Weber and Ellram, 1992). Secondly, the increased use of supply base reduction (SBR) further increases the buyer’s dependence upon its suppliers’ performance (Power et al., 2001). Thirdly, the fact that nowadays buyers and suppliers seek for a closer relationship, increases the role and contribution of suppliers in the performance of the purchaser (Heidi and John, 1990).

Furthermore, the supplier selection process cannot merely be described as one of extreme importance, but also as a process that is highly complex for two main reasons. Firstly, Weber et al. (1991) stress that the supplier selection process is highly complex due to the involvement of multiple and often conflicting criteria of both qualitative and quantitative in nature. To be able to obtain a satisfying supplier selection, potential suppliers are needed to be assessed against these criteria, and as these criteria might be conflicting (e.g. cost vs. quality) trade-offs are typically required (Chen et al., 2006). Secondly, the increased sourcing and purchasing opportunities provided by the intensified globalization of world trade, and the facilities of enhanced communication methods, is another factor which has increased the complexity of the supplier selection process (Luo et al., 2009; Kahraman and Kaya, 2010).

The complexity of supplier selection even further increases in the case of agile environments. These environments are characterized as highly dynamic due to rapidly changing actions of competitors, market conditions, consumer demands, and so on (Hakansson and Snehota, 2006). Luo et al. (2009) argue that, in order to cope with the dynamic environment, the task of supplier selection should be one of frequent occurrence. In addition, Sarkis (2001) adds that, in agile environments, the supplier selection task ought to be conducted broader and faster.

2.1. Supplier selection methods

Conceptual supplier selection methods frequently define multiple subsequent phases (e.g. De Boer et al., 2001; Luo et al., 2009; Monczka et al., 2011). A general principle of these multiple-phase approaches is that the initial set of identified potential suppliers is
screened, after which the “qualified” suppliers are subjected to further scrutiny. These two subsequent phases can be defined as qualification phase and final choice phase, respectively. Due to the importance of these two phases for the supplier selection methodology in this research, briefly appropriate methods for both phases will be discussed.

2.1.1. Qualification methods

The first two methods suitable for the qualification phase are the categorical method and cluster analysis. They seem similar approaches, where suppliers are grouped into categories with the objective to maximize the differences between suppliers of different groups, while at the same time minimizing the differences between suppliers in the same group, on a distinct set of criteria. However, the difference between both methods is that the categorical method is qualitative in nature (e.g. positive, neutral, negative) (Timmerman, 1986), whereas the cluster analysis is based on assessment by means of numerical scores. DEA is another possible method which was applied by Weber and Desai (1996) and Liu et al. (2000). Here, “for each vendor an index of relative vendor efficiency (RVE) is constructed in order to operationalize the concept of vendor performance” (Weber and Desai, 1996: p. 143). Ng et al. (1995) developed a CBR-system for the purpose of screening suppliers that provides the buyer information from similar decision situations by means of a software-driven database. Finally, conjunctive, disjunctive and lexicographical screening methods are proposed as possibilities for qualification purposes (De Boer et al., 2001).

2.1.2. Final choice methods

For the final choice phase, three most frequently applied methods can be identified: (1) Rating and linear weighting models; (2) Total cost approaches; (3) Mathematical programming models.

The most frequent applied linear weighting models in supplier selection problem is the analytical hierarchy process (AHP) (e.g. Barbarosoglu and Yazgac, 1997; Chan et al., 2007). AHP is a multi-criteria decision making (MCDM) method which forms the supplier selection problem into a hierarchy that allows structuring and modeling of a complex decision into smaller parts at different levels (Saaty, 1980). Saaty (1980) argues that AHP is suitable for supplier selection due to its inherent capability to take both qualitative and quantitative criteria into consideration. A drawback of AHP is the need for exact judgments (crisp numbers) from the decision makers to perform comparisons. Furthermore, it must be noted that the AHP is a fully compensatory method.

“Total cost of ownership (TCO) quantifies all costs associated with the purchasing process throughout the entire value chain of the firm” (Degraeve et al., 2000: p. 35). The approach goes beyond price to consider all costs over an item’s entire life within the organization, such as among others the costs related to service, quality, delivery, administration, communication, failure, and maintenance (Ellram, 1994). However, although TCO approaches have been argued to make purchasing more value oriented, the quantification of all criteria simultaneously forms a major drawback due to the fact that, in practice, it is hard to quantify and monetize all supplier selection related factors (e.g. risks, and environmental and social costs).

Mathematical programming models offer the opportunity to formulate a decision problem in terms of a mathematical objective function. An advantage of mathematical programming models is that they are more objective than rating and linear weighting models due to the fact that the DM explicitly has to state objective functions (De Boer et al., 2001). A disadvantage, similar as to TCO approaches, is that mathematical programming models can solely consider quantitative criteria (Degraeve et al., 2000).

3. Proposed supplier selection methodology

For the purpose of supplier selection of airline retail, this research proposes the “Funnel Methodology for Supplier Selection”. The methodology proposes two main phases to execute the supplier selection: Phase 1: Qualification, and Phase 2: Final choice. Phase 1 proposes the application of a conjunctive screening method. Phase 2 proposes the application of a fuzzy AHP to rank the most suitable suppliers. The individual phases will be further explained below.
3.1. Qualification phase

“When there are a large number of alternatives, deciding which option to choose becomes a formidable task” (Rossi, 2006: p. 254). Hence, the first main objective of the qualification phase is to reduce the total number of initial potential suppliers to a number of “qualified” suppliers prior to the final choice phase. The second main objective of the qualification phase is to effectively cope with the possible adverse effects occurring due to the fully compensatory nature of the fuzzy AHP applied in the final choice phase.

To achieve both objectives, the methodology proposes the application of a 
conjunctive screening method. The conjunctive screening method is frequently applied in marketing choice models (e.g. Gilbride and Allenby, 2004; Rossi, 2006), and lends itself well to restrict a set of alternatives prior to analysis by other, more complex, decision making methods (Linkov et al., 2004). The conjunctive screening method uses conjunctive screening rules, implying that an alternative must meet a minimal performance threshold, or cut-off value, for each identified criterion in order to qualify to the final choice phase. Hence, the importance of the criteria in this first method is considered equal.

Suppose the supplier selection has to be made among \( n \) alternatives \((i = 1, 2, ..., n)\) characterized by a vector of criteria \( C_i \) with \( m \) elements \( \{C_{i1}, C_{i2}, ..., C_{im}\} \). Through the conjunctive screening rules, alternatives to be taken into further consideration in the final choice phase are identified using an indicator function, \( I \left( C_{im} > \gamma_m \right) \), that equals one if the value of criterion \( m \) for alternative \( i \) is greater than the defined cut-off value \( \gamma_m \). In order for an alternative to qualify to the final choice phase, the indicator function must be equal to one for all \( M \) attributes. Thus alternative \( j \) qualifies if result is one, using:

\[
I(C_i, \gamma) = \prod_m I(C_{im} > \gamma_m)
\]  

(1)

3.2. Final-choice phase

As mentioned earlier, a major advantage of the AHP is its ability to cope with quantitative as well as qualitative criteria. Yet, a frequently mentioned drawback of AHP is the need for exact judgments (crisp numbers) from the DMs to perform the pair-wise comparisons. However, the use of Fuzzy Set Theory (FST) diminishes this drawback substantially (Kahraman, et al., 2003). Hence, for the purpose of selecting the most suitable supplier(s), among the obtained set of qualified suppliers from the qualification phase, this research proposes the use of a fuzzy AHP in the final choice phase. Below, a further explanation of AHP, FST, and the specific fuzzy AHP applied in this research is provided.

3.2.1. AHP

The AHP, first introduced by Saaty (1980), is an MCDM-method that allows systematic structuring and modeling of a complex decision making problem. This is achieved through forming a hierarchy in which the decision making problem is structured into smaller parts at different levels. AHP can be applied in decision making problems where DMs and experts are available. The DM needs to have a (quantifiable) goal, and needs to be able to distinguish alternative solutions to achieve that goal, whereas the experts are needed in order to assess the alternative solutions against the criteria (Rezaei et al., 2013).

AHP divides the decision making process into the following three main steps (Saaty, 1980):

1. Problem structuring;
2. Assessment of local priorities; and
3. Calculation of global priorities.

3.2.2. Fuzzy set theory

In his seminal work, Zadeh (1965) designed the fuzzy set theory (FST) as a mathematical means to quantify inherent fuzziness to deal with uncertainty and vagueness of human thinking, which is constantly present in real life problems. Since knowledge can be applied in a more natural way by using FST, many decision making problems can be simplified. Fuzziness can be defined as a type of imprecision which may be affiliated with sets in which a distinct transition from membership to non-membership is lacking (Belmann and Zadeh, 1970). Fuzzy sets are then characterized by a membership function, which assigns a grade of membership ranging between zero and one to each object (Kahraman et al., 2003). In mathematical terms fuzzy set \( X \)
of universe of universe $Y$ is defined by function $\mu_x(y)$, and can be expressed as in equation 2 (Negnevitsky, 2002):

$$\mu_x(y) : Y \rightarrow [0,1]$$

When applying FST, authors commonly use triangular fuzzy number (TFNs) due to its ability to effectively capture the vagueness in human’s verbal assessments (Bevilacqua et al., 2006). A fuzzy number $M$ on $\mathbb{R} = (-\infty, +\infty)$ is defined to be a TFN if its membership function $\mu_M(x): \mathbb{R} \rightarrow [0,1]$ is equal to (Van Laarhoven and Pedrycz, 1983):

$$\mu_M(x) = \begin{cases} \frac{x-l}{m-l}, & l \leq x \leq m, \\ \frac{u-x}{u-m}, & m \leq x \leq u, \\ 0, & \text{otherwise}. \end{cases}$$

In the equation above $l \leq m \leq u$, where $l$ and $u$ stand for the lower and upper bound of the support of fuzzy number $M$, respectively, and $m$ for the modal value ($l \neq m \neq u$). A TFN, as expressed by equation 4 will be denoted as $(l, m, u)$, see Fig. 1.

![Fig. 1. Membership function of a triangular fuzzy number (Van Laarhoven and Pedrycz, 1983)](image)

In addition, Van Laarhoven and Pedrycz (1983) developed the following basic operations for TFNs $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$ as formulated in equation 5–9.

**TFN addition:**

$$M_1 \oplus M_2 = (l_1, m_1, u_1) \oplus (l_2, m_2, u_2) = (l_1 + l_2, m_1 + m_2, u_1 + u_2)$$

**TFN subtraction:**

$$M_1 \ominus M_2 = (l_1, m_1, u_1) \ominus (l_2, m_2, u_2) = (l_1 - l_2, m_1 - m_2, u_1 - u_2)$$

**TFN multiplication,** where $l_0, m_0, u_0$ are all positive real numbers:

$$M_1 \otimes M_2 = (l_1, m_1, u_1) \otimes (l_2, m_2, u_2) = (l_1 \times l_2, m_1 \times m_2, u_1 \times u_2)$$

**TFN division,** where $l_0, m_0, u_0$ are all positive real numbers:

$$M_1 \oslash M_2 = (l_1, m_1, u_1) \oslash (l_2, m_2, u_2) = \left( \frac{l_1}{u_2}, \frac{m_1}{m_2}, \frac{u_1}{l_2} \right)$$

TFN’s reciprocal fuzzy number $\hat{a}_{ij}$ can be obtained by using the following equation:

$$\hat{a}_{ij} = \frac{1}{a_{ij}} = (l_{ij}, m_{ij}, u_{ij})^{-1} = (\frac{1}{u_{ij}}, \frac{1}{m_{ij}}, \frac{1}{l_{ij}})$$

### 3.2.3. Improved fuzzy AHP using FPP

This research proposes to use the improved version of the fuzzy AHP using fuzzy preference programming (FPP) as developed by Rezaei et al. (2013). A main merit of using this particular method is that, instead of fuzzy priority weights, crisp priority weights will be obtained from the initial fuzzy comparison judgments. Rezaei et al. (2013: p. 2751) define the following three main steps of the improved fuzzy AHP using FPP:

**Step 1.** Establish the hierarchy

The constructed hierarchy should comprise a goal, criteria, sub-criteria, (sub-sub-criteria and so on,) and decision alternatives.

**Step 2.** Determine the pair-wise comparison matrices

As mentioned earlier, TFNs as defined in equation 4 will be used for the pair-wise comparisons. Similar to comparison matrices in conventional AHP, a fuzzy $(n \times n)$ comparison matrix $A = [a_{ij}]$, in which element $a_{ij}$ indicates the relative importance of decision criterion $C_i$ over decision criterion $C_j$ with respect to its parent element, can be expressed as:

<table>
<thead>
<tr>
<th></th>
<th>$C_1$</th>
<th>$C_2$</th>
<th>$C_3$</th>
<th>...</th>
<th>$C_n$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_1$</td>
<td>1</td>
<td>$\hat{a}_{12}$</td>
<td>$\hat{a}_{13}$</td>
<td>...</td>
<td>$\hat{a}_{1n}$</td>
</tr>
<tr>
<td>$C_2$</td>
<td>$\hat{a}_{21}$</td>
<td>1</td>
<td>$\hat{a}_{23}$</td>
<td>...</td>
<td>$\hat{a}_{2n}$</td>
</tr>
<tr>
<td>$C_3$</td>
<td>$\hat{a}_{31}$</td>
<td>$\hat{a}_{32}$</td>
<td>1</td>
<td>...</td>
<td>$\hat{a}_{3n}$</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$C_n$</td>
<td>$\hat{a}_{n1}$</td>
<td>$\hat{a}_{n2}$</td>
<td>$\hat{a}_{n3}$</td>
<td>...</td>
<td>1</td>
</tr>
</tbody>
</table>
where $\tilde{a}_{ij} = (l_{ij}, m_{ij}, u_{ij})$ is a TFN, and its fuzzy reciprocal $\tilde{a}_{ji}$ can be derived by using

$$\tilde{a}_{ji} = 1/\tilde{a}_{ij} = \tilde{a}_{ij}^{-1} = (l_{ij}^{-1}, m_{ij}^{-1}, u_{ij}^{-1}) = \left(\frac{1}{m_{ij}}, \frac{1}{l_{ij}}, \frac{1}{u_{ij}}\right).$$  \hspace{1cm} (10)

This research uses TFNs as depicted in Fig. 2, where “1” defines that A and B are equally important, and “9” defines that A is extremely more important than B.

Since the fuzzy pair-wise comparison matrix is a reciprocal one, only the elements of the upper right part are used for calculation of the weights by the proposed FPP method” (Mikhailov and Tsvetinov, 2004: p. 30). Hence, it suffices that the DM provides $n(n-1)/2$ pair-wise comparisons $\tilde{a}_{ij}, i = 1, 2, \ldots, n$, $j = 2, 3, \ldots, n, j > i$ (Rezaei et al., 2013).

Step 3. Derive crisp priority vector $w = (w_1, w_2, \ldots, w_n)^T$ from the fuzzy pair-wise comparisons using FPP

“In this step, the aim is to determine the relative weight of the criteria $w = (w_1, w_2, \ldots, w_n)^T$ such that the ratios $w_i/w_j$ are approximately within the scopes of the pair-wise judgment $\tilde{a}_{ij}$, or equivalently” (Rezaei et al., 2013: p. 2751):

$$l_{ij} \leq \frac{w_i}{w_j} \leq u_{ij}$$  \hspace{1cm} (11)

Rezaei et al. (2013) claim that in fuzzy AHP two distinctive types of fuzzy numbers can be defined, namely:

- **Type I**: TFNs 1, 2, 3, ..., 9. As, for example, TFN 2 = (1, 2, 3), which has a membership function as depicted in Fig. 3.

- **Type II**: Corresponding reciprocals of the Type I TFNs, 1/9, 1/8, 1/7, ..., 1/2, 1. As, for example, the reciprocal of TFN 2, i.e. fuzzy number 1/2 = (1/3, 1/2, 1), which has a membership function as depicted in Fig. 4 (non-dashed).

With respect to equation 11, it must be noted that there might be many $w_i$ and $w_j$ that satisfy this inequality. Hence, to be able to reflect a DM’s satisfaction of differing $w_i/w_j$ ratios, the following two membership functions are expressed:

$$\mu_{ij}(\frac{w_i}{w_j}) = \begin{cases} \frac{w_i}{w_j} - l_{ij}, & w_i \leq m_{ij}, \\ u_{ij} - \frac{w_i}{w_j}, & w_i \geq m_{ij}. \end{cases}$$  \hspace{1cm} (12)

$$\mu_{ji}(\frac{w_j}{w_i}) = \begin{cases} \frac{w_j}{w_i} - l_{ij}, & w_j \leq m_{ij}, \\ u_{ij} - \frac{w_j}{w_i}, & w_j \geq m_{ij}. \end{cases}$$  \hspace{1cm} (13)

Equation 12 ought to be used for Type 1 TFNs, while equation 13 ought to be used for Type 2 TFNs. Next, following the logic as described by Mikhailov (2003), the improved version of FPP can be formulated as follows (Rezaei et al., 2013):

Maximize $\lambda$, subject to

$$(m_{ij} - l_{ij})\lambda w_i - w_i + l_{ij} w_j \leq 0,$$

$$(u_{ij} - m_{ij})\lambda w_j + w_i + u_{ij} w_j \leq 0,$$

$$(m_{ji} - l_{ji})\lambda w_i - w_i + l_{ji} w_j \leq 0,$$

$$(u_{ji} - m_{ji})\lambda w_j + w_i + u_{ji} w_j \leq 0.$$  \hspace{1cm} (14)

$$\sum_{k=1}^{n} w_k = 1,$$

$$w_k > 0,$$

$i = 1, \ldots, n - 1, j = 2, \ldots, n, j > i, k = 1, \ldots, n$
Solving the non-linear problem as expressed in equation 14 should lead to the optimal priority vector \( w^* \) and \( \lambda^* \). It must be noted that the priority weights obtained in this step are local priority weights. With respect to consistency, Rezaei et al. (2013: p. 2751) state that “a fuzzy positive reciprocal matrix \( \tilde{A} = [\tilde{a}_{ij}] \) is consistent if and only if \( \tilde{a}_{ik} \otimes \tilde{a}_{kj} = \tilde{a}_{ij} \) where the fuzzy positive matrix \( \tilde{A} = [\tilde{a}_{ij}] \) is reciprocal if and only if \( \tilde{a}_{ij} = \tilde{a}_{ji}^{-1} \) and \( \tilde{a}_{ii} = 1 \forall \ i \)”. Furthermore, in order to measure the consistency in the fuzzy AHP using FPP, the optimal value \( \lambda^* \), obtained from solving the non-linear problem as expressed in equation 14, can be interpreted as consistency index. Positive values of \( \lambda^* \) indicate that the pair-wise comparisons are consistent, where \( \lambda^* = 1 \) indicates full consistency. Negative values of \( \lambda^* \) indicate that the pair-wise comparisons are strongly inconsistent.

With respect to step 3, it must be noted that the pair-wise comparisons will be conducted until and including the penultimate level of the AHP-hierarchy. However, in order to complete the supplier selection procedure, we would like to add another two steps:

**Step 4.** Assess decision alternatives against lowest level (sub-)criteria

Although the application of AHP requires pair-wise comparisons from each level, for the purpose of enhancing practical usability of the methodology for the envisioned users, the choice was made to use a five-point crisp Likert (1932) scale to derive performance judgments of the relevant decision alternatives (1 = extremely poor, 5 = extremely well).

**Step 5.** Aggregate performance judgments and global priorities to final AHP-scores

As the priorities obtained in step three represent the local priorities, firstly in this step, the global priorities of the sub-criteria must be obtained. These are obtained through aggregating all local priorities. Assume that global priorities \( w_i^* \) of \( C_i \) can be derived by using

\[
w_i^* = w_i \times \prod_{i=1}^{t} w_{\text{cluster}}^{(i)} \quad (15)
\]

where \( C_i \) has \( t \) upper clusters at different levels in the hierarchy, and \( w_{\text{cluster}}^{(i)} \) is the cluster weight of the \( i \)th upper cluster that contains \( C_i \) in the hierarchy. AHP-scores can then be derived using

\[
A_{\text{AHP-score}} = \sum_{j=1}^{m} a_{ij}w_i^* \quad (16)
\]

where \( a_{ij} \) represents the relative value of alternative \( A_j \) (\( j = 1, 2, \ldots, m \)) with respect to criterion \( C_i \) (\( i = 1, 2, \ldots, n \)), \( w_i^* \) represents the global priority of \( C_i \). The alternative with the highest overall score is obtained by using equation 17. This alternative is then suggested by the AHP as most suitable alternative.

\[
A_{\text{AHP-score}} = \max_{j} \sum_{i=1}^{m} a_{ij}w_i^* \quad (17)
\]

**4. Application of supplier selection methodology in airline retail**

Netherlands’ major airline company seeks to select the best suppliers with respect to their retail assortment. Airline retail can be broken down into discrete groups of physically related product items (e.g., Watches, Electronics, Fragrances). In this research we decided to investigate the Watches category. However, an identical supplier selection procedure could be executed to find the best suppliers regarding the other categories. To put things into perspective, the airline company’s retail turnover in 2012 amounted to €28 million.

**4.1. Qualification phase**

The supplier selection procedure commences by identifying initial potential suppliers. In this research, the initial potential suppliers were retrieved from the company’s supplier database. In this database, ten potential suppliers were identified. We will refer to them as Supplier A, B, ..., J.

Next, criteria to assess the suppliers against ought to be established. For the qualification-phase of this research, the following six criteria were established by means of literature review, and interviews with the DM and experts:

1. Cost/Price;
2. Product quality;
3. Delivery;
4. Financial stability;
5. CSR; and
6. Assortment.
The interpretation of the criteria will be elaborated upon section 4.2.

Supplier performances, i.e. impacts of alternatives on criteria, will be assessed as acceptable or unacceptable against the six specified criteria. Next, attribute levels acceptable and unacceptable are coded by integer values 1 and 0, respectively. The cut-off values can then be defined as $0 \leq \gamma_m < 1$, as, for example, 0.5. Table 1 summarizes the conjunctive screening rules as applied to this research.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Levels</th>
<th>Coded values</th>
<th>Cut-off value ($\gamma_m$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost/Price</td>
<td>Unacceptable</td>
<td>0</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>Acceptable</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Product quality</td>
<td>Unacceptable</td>
<td>0</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>Acceptable</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Delivery</td>
<td>Unacceptable</td>
<td>0</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>Acceptable</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Financial stability</td>
<td>Unacceptable</td>
<td>0</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>Acceptable</td>
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<td></td>
</tr>
<tr>
<td>CSR</td>
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<td>0.5</td>
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<tr>
<td></td>
<td>Acceptable</td>
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</tr>
<tr>
<td>Assortment</td>
<td>Unacceptable</td>
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<tr>
<td></td>
<td>Acceptable</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Next, supplier evaluations are obtained by conducting structured interviews with experts. In order for a supplier to qualify to the final choice phase, it must perform acceptable on each of the defined criteria, i.e. the indicator function $I(C_{im} > \gamma_m)$ must satisfy the conjunctive screening rule as expressed in equation 1. The supplier evaluations qualification phase in coded values, and their indicator function $I$ are presented in the Table 2. The results can be interpreted by means of stating that Supplier F, Supplier I, and Supplier J have been assessed to perform (at least) acceptable with respect to each of the six criteria, and therefore, have successfully passed the qualification phase. These three suppliers will now be subjected to further scrutiny in the final choice phase.

4.2. Final-choice phase

In the final choice phase, the defined steps in section 3.2.3. will be subsequently executed.

**Step 1. Establish the hierarchy**

The AHP-hierarchy is depicted in Fig. 5. The goal can be formulated as selecting the most suitable supplier. One level below the goal, the second level, represents the criteria classification. Again, one level lower, the third level, represents the criteria affiliated with the criteria classes. Subsequently, one level lower, the fourth level, represents the sub-criteria, affiliated with the criteria, against which the suppliers will be evaluated in step four. The lowest level, level five, represents the decision alternatives in terms of Supplier F, Supplier I, and Supplier J. The criteria and affiliated sub-criteria, which are adopted in the AHP-hierarchy, are explained in Table 3.
Fig. 5. AHP-Hierarchy
Table 3
Explanations of criteria affiliated sub-criteria

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Sub-criteria and explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1. Cost/Price</td>
<td>According to many authors (e.g. Dickson, 1966; Weber et al., 1991; Chen et al., 2006; Ho et al., 2010), cost/price is one of the most crucial, if not the most crucial, factors to take into account when selecting a supplier. Purchasing prices can be considered as a major determinant of a company’s ability to achieve competitiveness, and its ability to achieve high profit margins. In the context of this research, “product price” and “listing fee” (a fixed or commission based fee suppliers pay for presenting their items in the in-flight magazine) are primary determinants of price. In addition, “content related costs”, potential costs for photography, product descriptions, are taken into account. Last, “price erosion” or stability (Chan et al, 2007), the frequency with which prices increase, and “price transparency” of the supplier are considered.</td>
</tr>
<tr>
<td>A2. Product quality</td>
<td>Quality is a second criterion which has deserved an abundant amount of attention in the supplier selection literature (e.g. Dickson, 1966; Weber et al., 1991; Ho et al., 2010). First of all, in the context of this research quality refers to a supplier’s “product quality”. Important indicators of product quality are product’s “conformance to specifications and requirements” (Choi and Hartley, 1996), and the “average defect rate” (Wu and Barnes, 2010). Furthermore, “product sophistication/innovativeness” is an important factor to consider (Choy et al., 2003). Especially, if the market is subjected to frequent changing customer preferences and trends, as in the case of the airline retail market. “Product packaging” has two functions in airline retail: Firstly, attractive “product packaging” could serve as yet another means to convince a potential buyer into a purchase, secondly, compact product packaging is of crucial importance due to the restricted space in an airplane.</td>
</tr>
<tr>
<td>A3. Delivery</td>
<td>Delivery is yet another one of the most frequent used criteria in supplier selection (Ho et al., 2010). This criterion reflects on supplier reliability issues such as “compliance with predetermined due date” and “compliance with predetermined order quantity” (Chan et al., 2007). These aspects are fundamental supplier capabilities required to ensure minimization of disruptions of KLM’s operations. In addition, delivery reflects on a supplier’s agility in terms of its delivery speed or “lead time” (Wu and Barnes, 2011).</td>
</tr>
<tr>
<td>A4. Support services</td>
<td>In the context of this research, services reflect on supplier’s capabilities to add value to its primary service of product supply. Roughly, support services can be divided into, firstly, services prior to product delivery in terms of “provision of information”, referring to all communicational efforts from supplier towards the buyer, and secondly, (post-delivery) “after sales service” (Choi and Hartley, 1996). In addition, due to the importance for the airline company, the “ability to return/sell back” product items in case of disappointing sales numbers.</td>
</tr>
<tr>
<td>A5. (Delivery) Flexibility &amp;</td>
<td>As the concept of the agile supply chain received an increasing amount of attention among both academics and company supply chain managers to cope with complex and dynamic environments, increasingly supplier selection criteria related to flexibility and responsiveness are adopted. Correspondingly, in this research, this criterion is incorporated to be able to reflect on a supplier’s agility level. More specifically, the promptness with (responsiveness) and the degree to which (flexibility) a supplier can adjust its “lead time”, delivered “product volumes” (Sarkar and Mohapatra, 2006), and “product mix” (Wu and Barnes, 2010). In addition, this criterion takes into account a supplier’s “time-to-market” (Choy et al., 2003), i.e. the required time for a “new” product to be supplied when KLM expresses a particular product need.</td>
</tr>
<tr>
<td>Responsiveness</td>
<td></td>
</tr>
<tr>
<td>B1. Financial stability</td>
<td>Both suppliers and buyers seek supply chain partners, which have the ability to positively contribute to their relationship, especially in the case of longer term relationships. A supply chain partner who is financially unstable will be less able to do so. Therefore, it is important to consider the financial position when selecting a supplier (Ellram and Carr, 1994). As argued earlier, “financial stability” can be crucial in long-term business relationships, since, regardless of how good a supplier performs, an unstable financial situation can have disastrous</td>
</tr>
</tbody>
</table>
consequences for both suppliers and its customers (Chan et al., 2007). In addition, the airline’s desire to be able to “sell back” product items in case of disappointing sales figures, amplifies the importance of suppliers’ financial stability. Past experiences with financially unstable suppliers have resulted in disastrous consequences by means of the airline being stuck with unmarketable products, and its supplier ending up bankrupt.

**B2. Reputation**

A supplier’s reputation reflects on both a supplier’s “performance history” (Dickson, 1966), which is based on own experiences with a known supplier, and a supplier’s “reputation in the industry” (Chan et al., 2007), which includes opinions from other parties within the industry as well rather than from the airline alone. Reputation in the industry can be particularly useful for information gathering purposes on new suppliers (e.g. integrity and trustworthiness).

**B3. CSR**

The airline highly values its corporate social responsibility (CSR). As the airline frequently uses its CSR-performances as marketing means, misconduct from this perspective could lead to severe reputational damage with the possible consequence of a reduced demand of its products and services. Hence, KLM highly values the “CSR” of its partners. According to Leppelt et al. (2013: p. 4), “CSR contributes to a company’s credibility, and may serve as an enabler of trustful business relationships”. Furthermore, they argue that CSR is more and more regarded as a necessary prerequisite for potential B2B partners. As such, also KLM awards its business to suppliers with positive CSR-policies. Supplier’s “willingness to improve CSR” has been included in this criterion, because despite the fact that many organizations do not pursue strict CSR-policies yet, they are often willing to do so in order to deserve KLM’s business.

**B4. Media activities**

“Media activities” reflect the extent to which a supplier engages into promotional activities provided by the airline. Suppliers frequently opt to advertise in combination with their supplied product items. Advertisements can be placed in the in-flight catalogue (Holland Herald), World Business Class brochure, in-flight flyer, on sales trolleys, and as commercials on screens. Prices are per month, depending on the size (or length) and advertisement period.

**C1. Assortment**

“Retailers attempt to offer a balance among variety (number of categories), depth (number of stock-keeping units [SKUs] within a category), and service level (the number of individual items of a particular SKU)” (Mantrale et al., 2009: p. 71).

SKU, stock-keeping unit, is a term which is frequently used in the discipline of inventory management to identify distinct product items. Although Mantrale et al. (2009) refer to a retailer, in the context of this research, these three elements might as well reflect a supplier’s assortment.

As this research presumes the intention to reduce the number of utilized suppliers, i.e. shifting supply from a larger to a smaller number of suppliers, crucial importance is imposed on, firstly, a supplier’s ability to supply a larger number of SKUs (assortment depth) (Choy et al., 2003), secondly, a supplier’s ability to supply larger product volumes (service level/capacity) (Ogden, 2006), and thirdly, a supplier’s ability to supply product items of an increased number of product categories (assortment variety) (Cavusgil et al., 1995).

**C2. Market expertise**

This criterion reflects a supplier’s “market awareness” (Wu and Barnes, 2010), “market experience” (Dickson, 1966), and “sourcing ability”. Market awareness represents a supplier’s ability to rapidly identify and respond to changing market conditions and customer needs. Simpson et al. (2002: p. 36) stress the importance of a supplier’s market awareness by stating that “once suppliers have a good understanding of customer needs, they can improve their performance on specific dimensions” (Simpson et al., 2002: p. 36). Market experience represents a supplier’s experience in the airline retail market in general, and its experience with similar major airline companies as the airline itself. Sourcing ability represents a supplier’s ability to source the “right” product items and pro-actively offer these items to the airline. Although it could be argued that sourcing ability represents a combination of a supplier’s market awareness and pro-activeness in communication, it is decided to take the criterion into account separately due to its importance to the airline.
C3. Management & Organization

This criterion reflects a supplier’s organizational fit to engage with into a close long-term supplier-buyer relationship. A supplier’s management “desire for business” is an important sub-criterion as it indicates a supplier’s motivation to engage into and foster a long-term relationship with the airline. In addition, a supplier’s desire for business will contribute to the alignment of partnership goals, and could ease negotiations. Next, a supplier’s “organizational culture” must, at least to some extent, be in line with the airline’s culture in order to avoid misunderstandings, and, again, to be able to effectively align partnership goals. Furthermore, in order to achieve sustained competitive advantage, nowadays, “individual businesses no longer compete as solely autonomous entities, but rather as supply chains” (Lambert et al., 1998: p. 1). As the considered suppliers are the airline’s first tier suppliers, “commitment to continuous improvement in product and process” becomes an even more crucial factor (as opposed to higher tier suppliers) in achieving competitive advantage and business continuity. “Communication” is an important means in maintaining and fostering a supply chain relationship. Therefore, the supply chain partners should adopt a pro-active attitude in communicating towards each other. Lastly, the “existing relationship” with a supplier in terms of the level of trust and understanding could influence a supplier’s fit for a long-term relationship (Chan et al., 2007). As mentioned earlier, this aspect of a supplier contributes to a supplier’s sourcing ability. In short, Management & Organization considers the attitude and future prospects of a supplier with respect to a long-term relationship. Here, the alignment of partnership goals is essential as the partnership is designed to be a continuing relationship (Cheraghi et al., 2004).

Furthermore, for this research the choice was made to adopt a criteria classification, which distinguishes product/service-related criteria, supplier-related criteria, and strategy/relationship-related criteria. Product/service-related criteria take into account characteristics which directly reflect on the product- and service performances of a supplier. Supplier-related criteria represent characteristics which directly relate to a supplier. Strategy/relationship-related criteria comprise characteristics which relate to the utilized strategy and type of relationship between the airline company and its supplier.

**Step 2. Determine the pair-wise comparison matrices**

In this step, the DM is required to express his/her preferences on the relative importance of each criterion compared to the other criteria with respect to its parent criterion, which can then be captured in an \((n \times n)\) matrix. The process of pair-wise comparisons by the DM commences by comparing the criteria classes with respect to the goal. Next, the criteria are compared with respect to their “parent” criterion class. Last, the sub-criteria are compared with respect to their parent criteria. An example of a reciprocal fuzzy pair-wise comparison matrix is presented in Table 5. This table reflects the comparison of sub-criteria, affiliated with “product quality”, with respect to “product quality”. The TFNs are derived from the linguistic variables as indicated in Table 4.

<table>
<thead>
<tr>
<th>Table 4</th>
<th>Linguistic variables and corresponding TFNs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equally important</td>
<td>(1, 1, 1)</td>
</tr>
<tr>
<td>Moderately more important</td>
<td>(2, 3, 4)</td>
</tr>
<tr>
<td>Strongly more important</td>
<td>(4, 5, 6)</td>
</tr>
<tr>
<td>Very strongly more important</td>
<td>(6, 7, 8)</td>
</tr>
<tr>
<td>Extremely more important</td>
<td>(8, 9, 9)</td>
</tr>
</tbody>
</table>

**Step 3. Derive crisp priority vector**

\[ w = (w_1, w_2, \ldots, w_n) \]

In this step, the objective is to derive the relative weights of the criteria \( w = (w_1, w_2, \ldots, w_n) \) from the fuzzy pair-wise comparison matrices obtained in step 2. In order to obtain the relative weights of the (sub)-criteria, the non-linear problem, as expressed in equation 14, should be solved. The obtained weights represent the local priorities. In this research, the non-linear problem as expressed above was implemented and solved by means of the Solver tool in software package Microsoft Excel, which is based on a gradient search numerical algorithm. In addition, in this step, the optimal value \( \lambda^* \), which measures the consistency of the pair-wise comparisons, is obtained through solving the non-linear problem.
Table 5
Pair-wise comparison matrix with respect to “product quality” (A2.)

<table>
<thead>
<tr>
<th>Criteria Class</th>
<th>Local Priorities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product packaging</td>
<td>(1/6, 1/5, 1/4)</td>
</tr>
<tr>
<td>Conformance to specification</td>
<td>(1/6, 1/5, 1/4)</td>
</tr>
<tr>
<td>Product sophistication/innovativeness</td>
<td>(1/4, 1/3, 1/2)</td>
</tr>
<tr>
<td>Average defect rate</td>
<td>(1/4, 1/3, 1/2)</td>
</tr>
</tbody>
</table>

For illustration purposes, again, we use the comparison of sub-criteria affiliated with “product quality”. The sixth column of Table 5 presents the local priorities of their respective sub-criteria in the first column with respect to “product quality”. In addition, the table presents the obtained \( \lambda^* \) in the first column of the first row. The positive value of \( \lambda^* \) (0.372) indicates that the pair-wise comparisons were conducted in a consistent manner.

**Step 4. Assess decision alternatives against lowest level (sub-)criteria**

For the evaluation of suppliers, represented by the lowest level of the hierarchy, against the sub-criteria, crisp judgments on an ordinal five-point Likert (1932) scale are used. For this purpose, the retail buyers were used for a vast majority of the supplier evaluations. For the evaluation with respect to sub-criteria of a more logistics operations nature (number: 6-10-11-12-14-16-17-18-28), an inventory planner was used.

**Step 5. Aggregate performance judgments and global priorities to final AHP-scores**

In this step, first the global priorities must be derived from the earlier obtained local priorities. The global priority of each sub-criterion can be obtained through multiplication of a sub-criterion’s local priority weight, the local priority weight of its parent criterion, and the local priority weight of the criteria class it belongs to. Mathematically, global priorities derived by using equation 15. The global priorities of the criteria classes, criteria, and sub-criteria are presented in Table 7.

Finally, through aggregation of the supplier evaluations of step 4, and the calculated priorities, the final suppliers scores are obtained. For this purpose, we used equation 16. This lead us to the final supplier scores and ranks, presented in Table 6.

Table 6
Final supplier scores and ranks

<table>
<thead>
<tr>
<th>Supplier</th>
<th>Score</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>3,303</td>
<td>3</td>
</tr>
<tr>
<td>I</td>
<td>3,541</td>
<td>1</td>
</tr>
<tr>
<td>J</td>
<td>3,390</td>
<td>2</td>
</tr>
</tbody>
</table>

5. Results and discussion

As can be observed from Table 6, Supplier I receives the highest final score with 3,541 (out of 5), and is therefore recognized as the most suitable supplier. Second place is awarded to Supplier J with a final score of 3,390, followed by Supplier F with a final score of 3,303.

With respect to the specific industry in which this research was conducted, a number of conclusions can be drawn. Firstly, we reflect on a number of industry specific supplier selection criteria that have been identified. Secondly, we reflect on a number of criteria that have proven to be of peculiar importance for the airline company. Criteria importances in terms of their respective priorities are presented in Table 7.

Firstly, the serious restrictions, which are imposed by the lack of space in terms of volume on an airplane, increase the complexities of retail in the airline industry. Regarding supplier selection, this expresses itself in the supplier selection criterion of “product packaging”. In addition, “product packaging” represents the attractiveness of products, which is of importance due to the direct interface with consumers.

Secondly, since in an airplane, the complete retail assortment is offered to the consumer by means of a catalogue, sales numbers are (partly) dependent on the
Table 7
Criteria classes, criteria and sub-criteria with corresponding global priorities

<table>
<thead>
<tr>
<th>Criteria classes</th>
<th>Global priorities</th>
<th>Criteria</th>
<th>Global priorities</th>
<th>Sub-criteria</th>
<th>Global priorities</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: Product-related</td>
<td>0,455</td>
<td>A1. Cost/Price</td>
<td>0,114</td>
<td>1. Product price</td>
<td>0,066</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2. Listing fee</td>
<td>0,021</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3. Price erosion</td>
<td>0,010</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4. Content related cost</td>
<td>0,008</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5. Cost transparency</td>
<td>0,008</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A2. Product quality</td>
<td>0,114</td>
<td>6. Average defect rate</td>
<td>0,018</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7. Conformance to specification</td>
<td>0,044</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8. Product sophistication/innovativeness</td>
<td>0,044</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9. Product packaging</td>
<td>0,008</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A3. Delivery</td>
<td>0,114</td>
<td>10. Lead time</td>
<td>0,010</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>11. Compliance with predetermined due date</td>
<td>0,052</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>12. Compliance with predetermined order quantity</td>
<td>0,052</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A4. Support services</td>
<td>0,057</td>
<td>13. After sales service</td>
<td>0,011</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>14. Provision of information</td>
<td>0,023</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>15. Ability to return/sell back</td>
<td>0,023</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A5. (Delivery) Flexibility &amp; Responsiveness</td>
<td>0,057</td>
<td>16. Volume flexibility and responsiveness</td>
<td>0,009</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>17. Product mix flexibility and</td>
<td>0,009</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>18. Lead time flexibility</td>
<td>0,009</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>19. Time-To-Market</td>
<td>0,028</td>
</tr>
<tr>
<td>B: Supplier-related</td>
<td>0,455</td>
<td>B1. Financial stability</td>
<td>0,225</td>
<td>20. Financial stability</td>
<td>0,225</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B2. Reputation</td>
<td>0,040</td>
<td>21. Reputation in the industry</td>
<td>0,020</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B3. CSR</td>
<td>0,095</td>
<td>22. Performance history</td>
<td>0,020</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>23. CSR</td>
<td>0,071</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B4. Media activities</td>
<td>0,095</td>
<td>24. Willingness to improve CSR</td>
<td>0,024</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C1. Assortment</td>
<td>0,039</td>
<td>25. Media activities</td>
<td>0,095</td>
</tr>
<tr>
<td>C: Strategy/Relationship-related</td>
<td>0,091</td>
<td>C2. Market expertise</td>
<td>0,039</td>
<td>26. Assortment depth</td>
<td>0,014</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>27. Assortment variety</td>
<td>0,004</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>28. Service level/Capacity</td>
<td>0,021</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C3. Management &amp; Organization</td>
<td>0,013</td>
<td>29. Market awareness</td>
<td>0,012</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>30. Market experience</td>
<td>0,004</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>31. Sourcing ability</td>
<td>0,022</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>32. Desire for business</td>
<td>0,004</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>33. Organizational culture</td>
<td>0,004</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>34. Commitment to continuous improvement in product and partnership</td>
<td>0,004</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>35. Communication</td>
<td>0,002</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>36. Existing relationship</td>
<td>0,001</td>
</tr>
</tbody>
</table>
attractiveness of a product’s presentation. However, attractive presentations incur costs. These costs could vary among suppliers, and therefore, “content related costs” are of importance in supplier selection.

Thirdly, the airline company provides third parties a considerable platform to engage into promotional media activities. These promotional activities constitute a substantial source of income for the airline company. However, the degree to which a supplier is willing to engage into media activities varies among suppliers, and is therefore of importance when selecting a supplier.

Fourthly, although additional promotional media activities can be opted for voluntarily by suppliers, for each listed product in the catalogue a “listing fee” ought to be remunerated by the supplier. Again, the favorability of treatment with respect to the listing fee varies among suppliers, and hence, are important to consider when selecting one.

Fifthly, since the airline company’s customer is the consumer, the identification of evolving consumer needs is of crucial importance. In addition to its own efforts to identify these evolving needs, the airline company highly values its supplier’s efforts in product development. This aspect in combination with a supplier’s degree of proactivity in offering these products have proven to be of importance for the airline company in supplier selection. These two aspects are captured in the criterion of “sourcing ability”.

Sixthly, since the sales of retail products are often hard to predict, the airline company endeavors to reduce its financial risks by means of returning, or “selling back”, retail products in case of disappointing sales numbers. However, since not every supplier provides this opportunity, this again, is an important factor to take into account in supplier selection.

In addition to the identification of criteria dedicated to the specific industry, conclusions can be drawn with respect to the importance of criteria. In order to gain comprehensive insights, we reflect on higher level criteria, which are presented in the fourth column of Table 7.

Firstly, “financial stability” has received the highest priority of the criteria. As also explained in Table 3, this can be attributed to the fact that the airline company deliberately highly values a supplier’s financial stability in an endeavor to minimize both its own and its supplier’s financial risks.

Secondly, “cost/price”, “product quality”, and “delivery” have received the second highest priorities. This observation is in line with the literature which argues that main supplier selection criteria should correspond to competitive priorities of cost, quality, and delivery (Aksoy and Ozturk, 2011).

Thirdly, “CSR” and “media activities” have proven to be important criteria. Since airline companies are often put forward as serious polluters to the environment, it is important to diminish this harmful image by emphasizing CSR. This goes beyond the optimization of their own corporate CSR, and includes the CSR of their partners. Next, as mentioned earlier, revenues generated from “media activities” constitute a substantial source of income for the airline company.

6. Validation of the methodology

In this section we study the validity of the developed methodology. With regard to the qualification phase, expert opinions were used as a means for validation. They were consulted on the issue whether the conjunctive screening method produced the correct results in terms of qualified suppliers. As both retail buyers fully agreed with the obtained set of qualified suppliers, the first phase of the methodology can be considered to be validated.

With respect to the final choice phase, Dagdeviren and Yüksel (2008) argue that there is no prevalent way to test the validity of an AHP-model. Moreover, Dagdeviren and Yüksel (2007) mention that authors commonly struggle with endeavors to validate their AHP-model. As main reason for this, they point out the manner in which priorities are derived from the pair-wise comparison judgments, which are based on the subjective opinions of DMs and experts. Still, two relevant validation tests for this research can be identified in the literature. Firstly, Saaty (2005) advocates for the use of expert opinions to validate an AHP-model. Accordingly, Ngai (2003), and Dagdeviren and Yüksel (2007) used expert opinions in practice to validate the outcome of their developed ANP and AHP-model, respectively. Second,
Dagdeviren and YükseL (2007), and Rezaei et al. (2013) used the optimal values of \( \lambda^* \), which can be interpreted as consistency index, for validation purposes of their developed fuzzy AHP models.

Correspondingly, these two validation tests where selected to test the validity of the application of the fuzzy AHP in this research. For the first test, the expert opinions of the DM were used in order to reflect on the obtained intermediate and final outcomes of the proposed fuzzy AHP. The DM described the gained insights and results as meaningful and useful in supporting the supplier selection decision making. For the second test, the optimal values \( \lambda^* \), obtained from solving the non-linear problem as expressed in equation 14, were interpreted. As explained in section 3.2.3, positive values of \( \lambda^* (> 0) \) indicate that the pair-wise comparisons are consistent, where \( \lambda^* = 1 \) indicates full consistency. Negative values of \( \lambda^*(< 0) \) indicate that the pair-wise comparisons are strongly inconsistent. Since all optimal values of \( \lambda^* \) are positive, moreover, since a majority of the optimal \( \lambda^* \) values are equal or close to 1, the conclusion can be drawn that the obtained priorities are consistent and comply with the DM’s opinion.

Since the fuzzy AHP-model successfully passed the first and second validity test, the conclusion can be drawn that the methodology has been successful validated.

7. Conclusion and future research

In this section we reflect on the earlier expected scientific contributions, and we propose a number of avenues for future research.

Firstly, by means of identification of (airline) retailer’s specific supplier selection criteria a contribution is made to science by providing insights into both supplier selection from a retailer’s perspective, and into the supplier selection in the airline industry. Similarly, the derived priorities of the respective criteria provide insights into importance of the adopted criteria in supplier selection from a retailer’s perspective, and into the supplier selection in the airline industry.

Secondly, with respect to the application of the “improved version of fuzzy AHP using FPP” developed by Rezaei et al. (2013), the conclusion can be drawn that it has proven its value by providing a highly sophisticated, yet, relatively easily applicable, methodology to solve complex supplier selection problems. An additional quality of this methodology is that it automatically provides the user with consistency indices of the pair-wise comparisons, which can subsequently be used for validation purposes (Rezaei et al., 2013). This is an extremely valuable additional quality since authors commonly struggle with endeavors to validate their AHP-model.

Thirdly, with respect to the two phased-methodology, the implementation of the qualification phase has proven to be highly effective in achieving its two main objectives: Firstly, by means of considerably reducing the number of suppliers prior to comprehensive assessment in the final choice phase (to diminish the exhaustiveness of the overall supplier selection procedure), and secondly, by means of accomplishing that each of the qualified suppliers were evaluated to perform at least acceptable in the final choice phase with regard to the adopted criteria in the qualification phase. The latter inference implying that no adverse effects due to the compensatory nature of the AHP were allowed by the methodology.

With regard to future research we recommend to investigate the general applicability of the developed supplier selection methodology in the airline retail industry. For this purpose, a survey involving multiple major airline companies could be conducted. Similarly, the general applicability of the developed supplier selection methodology in conventional retail could be investigated by means of conducting a survey involving retailers outside the airline industry. In addition, future research is proposed to integrate the fuzzy AHP using FPP with a mathematical programming model in order to determine the most suitable supplier(s) in combination with the optimal lot-sizes.
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