Using Fuzzy AHP to manage Intellectual Capital assets: An application to the ICT service industry

Armando Calabrese, Roberta Costa *, Tamara Menichini

Department of Enterprise Engineering, University of Rome Tor Vergata, Italy

**ARTICLE INFO**

**Keywords:**
- Benchmarking
- Intellectual Capital
- Fuzzy AHP
- Multi-criteria decision making
- Knowledge management

**ABSTRACT**

In today’s competitive business environment, Intellectual Capital (IC) management is ever more recognized as a fundamental factor in gaining competitive advantage. Actually, most firms have only a vague idea of how to manage investments in IC and what they should obtain from these investments. As a result, many companies overlook to balance IC investments, overinvesting in some IC components and neglecting others. Following this lead, the aim of the paper is to assess the relative importance of IC components, with respect to their contribution to the company value creation, in order to obtain guidelines for IC management and investments.

We propose a model for IC evaluation by integrating Fuzzy Logic and Analytic Hierarchy Process (AHP). This Fuzzy AHP approach allows to capture and foster IC dynamics: experts and managers are greatly supported by the use of linguistic variables in the evaluation process of the company intangible assets.

Finally, the application of the Fuzzy AHP methodology to a group of ICT service companies is presented.

**1. Introduction**

In order to obtain and maintain competitiveness companies must understand how to manage their intangibles by effectively increasing, spreading and exploiting them in the organization (Stewart, 1997). Indeed, business performance depends in great measure on an efficient management of Intellectual Capital (IC) and, consequently, IC evaluation is a critical obstacle to gain and maintain competitiveness. For this reason, the general attention for Knowledge Management approaches to understanding the nature of the firm and the possible basis for sustained competitive advantage, has been nurturing the interest for developing IC assessment methodologies (Spender & Marr, 2006).

Scientific literature on IC regards accounting rules as generally inadequate to completely appraise the economic value of intangible assets (Hand & Lev, 2003; Lev, 2003; Lev & Zambon, 2003), even after the adoption of IAS 38 (Morricone, Oriani, & Sobrero, 2010). The lack of an exhaustive response to company accounting needs regarding intangibles, caused the rise of alternative IC oriented forms of corporate reporting and the creation of new assessment methods. The new methods of measurement are often founded on different or even conflicting perspectives (e.g. monetary or non-monetary), but they all take into account the essential role that the IC plays in the knowledge-economy (Sveiby, 2001–2010).

Actually, most firms have only a vague idea of how to manage investments in IC and what they should obtain from these investments. As a result, many companies overlook to balance IC investments, because they overinvest in some IC components neglecting other ones (Zambon, 2003). Nevertheless, evaluating the importance of IC components is essential for any company that understands the new rules of survival in the knowledge-economy. More specifically, for a company it is important to understand how to manage IC creating and maintaining the right equilibrium among IC components (Lev, 2003). For example, if a service company invest too much in Human Capital neglecting its Structural Capital, tacit knowledge could overgrowth explicit knowledge, exposing the company to a high risk associated with personnel turnover.

In a real business scenario, many IC components are intangible in nature, therefore they are difficult or impossible to measure quantitatively. Actually, when measuring what are considered as intangible benefits, most experts provide linguistic assessments rather than exact numerical values to express their opinions (Costa & Evangelista, 2008). Following this lead, in this paper IC evaluation is realized by means of Fuzzy AHP, assessing the contribute of each IC component to the company value creation process. The methodology allows the comparison among companies of the same industry in the perspective of IC management improvement through benchmarking. Indeed, the aim of the analysis is to give guidelines to decision makers in order to create and preserve...
a valuable balance among IC components. Finally, the presented model is applied to the IC evaluation of a group of ICT service companies.

2. Measuring Intellectual Capital

In this paper we refer to IC utilizing the definitions by Roos, Roos, Dragonetti, and Edvinsson (1997), that describe the IC as complementary to the Financial Capital in the value creation process of a company. In their “Value Description Tree”, IC is determined as the combination of two main categories of intangibles:

- Human Capital that embodies the intangibles that are embedded in the company Human Resources. It is subdivided in three sub-components: “Competence” (competencies, skills and knowhow), “Attitude” (motivation and leadership) and “Intellectual Agility” (creativity, innovativeness, mental flexibility and problem solving).
- Structural Capital that defines the intangibles that are embedded in the organization. It is subdivided in three sub-components: “Relationship” (the company relational network with its stakeholders), “Organization” (structure, culture, routines and processes) and “Renewal and Development” (R&D, new projects, product and process innovations).

Both academics and practitioners regard IC as the keystone to obtain and maintain competitive advantage in today’s ever-competitive market (Cricelli & Grimaldi, 2008; Lev & Zambon, 2003), because they believe that an effective IC management has positive effects on company performance (Cheung, Lee, Wang, Chu, & To, 2003; Nakamura, 2003). Several studies deal with the issue of how IC management improves business performance generating value in the organization and there is evidence that investments in IC (i.e. R&D and innovation capital expenditure) have positive effects on a firm value and competitiveness (Huang & Liu, 2005; Tan, Plowman, & Hancock, 2007). Hand and Lev (2003) point out that IC has a positive impact on market value and business performance, being an indicator for future financial performance. Some authors also observe that different stakeholders may attribute a different financial value to different IC components (Chen, Cheng, & Hwang, 2005; Costa & Menichini, 2013). Generally, the greater efforts a company devotes to IC management, the greater performance and competitive advantage it receives in return (Lu, Wang, Tung, & Lin, 2010).

For these reasons, business performance nowadays depends in greater measure on an efficient management of intangibles, making the evaluation of IC components a critical obstacle to turning those investments into sources of competitive advantage (Campisi & Costa, 2012). Indeed, intangibles are the business aspect more difficult “to manage” because of the difficulty to correctly report in a financial statement their economic value and to identify the effect of each IC component on the enterprise performance (Lev & Zambon, 2003). Nevertheless, assessing the effectiveness of IC management is an important issue and the measures that are available are generally unsatisfactory: they do not allow the comparison of IC components among companies of the same industry (Wen, 2009), preventing the use of benchmarking, as a management tool, to create and preserve a valuable balance among IC components. For this reason, there is a necessity for a method that can compare companies of the same industrial sector with respect to the value of their IC components.

In this paper, we want to highlight the importance of measuring IC components in order to assess and to validate the effectiveness of IC strategies and to identify the most critical knowledge assets for achieving competitiveness. Following this lead, we propose a Fuzzy AHP method to assess the comparative importance of IC components, allowing a comparison between different firms of the same industry in the perspective of IC management improvement through benchmarking.

3. Using Fuzzy AHP to assess Intellectual Capital

Most IC components are intangible in nature, therefore they are difficult or impossible to measure quantitatively (Lev 2003; Sveiby, 2001–2010). For this reason, practitioners and managers are greatly supported by the use of multi-criteria method and fuzzy linguistic variables in the IC evaluation process. Indeed, AHP is suitable to assess the relative importance of IC components, allowing to consider both quantitative and qualitative criteria. Moreover, Fuzzy AHP, as an extension of the classic AHP method, enables to deal with the fuzziness and vagueness of linguistic judgments, establishing an effective prioritization of IC components.

3.1. The analytic hierarchy process

The AHP is a decision approach created to solve complex multiple criteria problems involving qualitative decisions (Saaty, 1980). Basically, decision makers have to decompose the goal of the decision process into its constituent parts, progressing, from the general to the specific perspective. In its simplest form, this structure must include a goal, criteria and alternative levels, ordered into a hierarchy. Each item (criterion, sub-criterion or alternative) would then be further divided into an appropriate level of detail. Once the hierarchy has been structured, decision makers judge the importance of each criterion in pair-wise comparisons, structured in matrices. The judgement is performed from the perspective of the direct upper level criterion.

The final scoring is on a relative basis, comparing the importance of one decision alternative to another. AHP captures both subjective and objective evaluations, also providing an useful mechanism for checking the consistency of the decision maker evaluations (Saaty, 1980). It can be used to analyze intangibles, because of the possibility to evaluate quantitative and qualitative criteria and alternatives on the same preference scale, namely a verbal one. In fact, IC components are attributes that have no scale of measurement, but can be quantified through relative measurement (priorities) (Grimaldi & Rippa, 2011; Saaty, Vargas, & Dellmann 2003; Schiuma & Carlucci, 2007). In addition, AHP is a subjective methodology where information and priority weights of elements can be obtained from decision makers using direct questioning or a questionnaire method.

3.2. The fuzzy analytic hierarchy process

Saaty’s AHP is often used to evaluate intangibles, but it does not completely capture the importance of qualitative aspects because its discrete scale cannot reflect the human thinking style (Özdagloğlu & Özdagloğlu, 2007). Indeed, when expert preferences are affected by uncertainty and imprecision, it is not very reasonable to use definite and precise numbers to represent linguistic judgments (Kwong & Bai, 2003). In order to deal with ambiguity, Triangular Fuzzy Numbers (TFNs) and AHP are integrated in the Fuzzy AHP approach to solve decision making problems concerning subjective evaluations. Fuzzy AHP converts linguistic judgments in TFNs organized in fuzzy pair-wise comparison matrices. These matrices are then processed to obtain the relative weights of items and the ranking of alternatives. A large number of methods are introduced to handle comparison matrices (Buckley, 1985; Chang, 1996; Custora & Buckley, 2001; Wang & Chin, 2006; Lee, 2010) and, among them, Chang’s method (1996) is widely used, due to its implementation simplicity to calculate relative weights. At the

3.3. Measuring Intellectual Capital
same time, this method presents some problematic aspects that may lead to a wrong prioritization of criteria and alternatives (Wang, Luo, & Hua, 2008). In order to overcome these problems, we propose an approach to calculate effectively the relative weights of decision criteria and alternatives. In this paper, the conversion scale used to convert linguistic judgments in TFNs is shown in Table 1.

4. The conceptual framework

Among methods introduced to obtain relative weights from fuzzy comparison matrices, the Chang’s method (1996) is widely applied. Nevertheless, Wang et al. (2008) demonstrate that it could lead to a wrong decision, because it may assign zero weights to some items (criteria, sub-criteria or alternatives), excluding them from the decision analysis. In the following paragraphs, we propose an approach to overcome Chang’s method limitations.

4.1. Review of Chang’s extent analysis method

According to Chang’s method, for each level of the constructed hierarchy, the pair-wise linguistic judgments are converted in fuzzy comparison matrices as follows:

\[
\tilde{A} = (\tilde{a}_{ij})_{n \times n} = \left[ \begin{array}{cccc}
(1,1,1) & \ldots & (l_{12}, m_{12}, u_{12}) & \ldots \\
(1,1,1) & \ldots & (l_{23}, m_{23}, u_{23}) & \ldots \\
\vdots & \vdots & \vdots & \vdots \\
(1,1,1) & \ldots & (l_{n1}, m_{n1}, u_{n1}) & \ldots \\
\end{array} \right]
\]

where:

\[
\tilde{a}_{ij} = (l_{ij}, m_{ij}, u_{ij}) = \frac{1}{n} \left[ \begin{array}{c}
l_{ij} \\
m_{ij} \\
u_{ij}
\end{array} \right] \quad i, j = 1, \ldots, n; \quad i \neq j
\]

represents the linguistic judgment for the items i and j; thus \(\tilde{A}\) is a square and symmetrical matrix.

For each row of \(\tilde{A}\) it is possible to calculate the relative row sum as:

\[
\tilde{r}_i = \sum_{j=1}^{n} \tilde{a}_{ij} = \left( \sum_{j=1}^{n} l_{ij}, \sum_{j=1}^{n} m_{ij}, \sum_{j=1}^{n} u_{ij} \right) \quad i = 1, \ldots, n
\]

By modifying the Chang’s normalization formula using the Wang and Elhag’s (2006) correction, it is possible to obtain the normalized row sum \(\tilde{S}_i\) as:

\[
\tilde{S}_i = \tilde{r}_i / \sum_{j=1}^{n} \tilde{r}_j = \left( \frac{l_{ij}}{l_{ij} + m_{ij} + u_{ij}}, \frac{m_{ij}}{l_{ij} + m_{ij} + u_{ij}}, \frac{u_{ij}}{l_{ij} + m_{ij} + u_{ij}} \right) \quad i = 1, \ldots, n
\]

The normalized row sums \(\tilde{S}_i\) are then compared using the degree of possibility (Fig. 1):

\[
V(\tilde{S}_i \geq \tilde{S}_j) = \begin{cases} 
1 & \text{if } m_i \geq m_j \\
\frac{m_i - m_j}{m_i - m_j + (u_i - l_i)} & \text{if } l_i < u_i, i, j = 1, \ldots, n; \ j \neq i \\
0 & \text{otherwise}
\end{cases}
\]

Finally, the relative crisp weight of each item i, is calculated normalizing the degree of possibility values:

\[
w_i = \frac{\sum_{j=1}^{n} V(\tilde{S}_i \geq \tilde{S}_j) j = 1, \ldots, n ; j \neq i}{\sum_{j=1}^{n} \sum_{j=1}^{n} V(\tilde{S}_i \geq \tilde{S}_j) j = 1, \ldots, n ; j \neq k} \quad i = 1, \ldots, n
\]

Wang et al. (2008) criticize this approach to calculate relative weights. First of all they state that the method may assign a zero weight to criteria or alternatives, implying their elimination as unnecessary items. This elimination could contrast with the hierarchical structure, leading to a wrong prioritization of criteria and alternatives. Moreover, they claim that the weights calculated using (6) cannot be considered as the relative importance of criteria and alternatives. For this reason, they assert that (6) is only useful to compare TFNs, because it expresses the highest intersection point of the membership functions related to \(\tilde{S}_i\) and \(\tilde{S}_j\) (see Fig. 1). Finally, Wang et al. (2008) state that if pair-wise comparison matrices (1) are consistent, crisp weights belong to the intervals defined by (4).

4.2. An innovative approach to determine Fuzzy AHP weights

In order to overcome Chang’s method limitations we propose a variation of his methodology that integrates Wang et al. (2008) review criticisms and Kwong and Bay’s (2003) approach for the consistency test. The employed methodology determines the relative importance of criteria, sub-criteria and alternatives by means of fuzzy comparison matrices (1), without incurring in the zero weight issue. This approach is based on the following steps:

Step 1: Convert the fuzzy comparison matrices (1) into crisp comparison matrices using the centroid defuzzification method called center of gravity (Yager, 1981). In case of TFNs the translating formula is (Wang & Elhag, 2007):

\[
a_{ij}(\tilde{a}_{ij}) = \frac{l_{ij} + m_{ij} + u_{ij}}{3}
\]

where \(\tilde{a}_{ij} = (l_{ij}, m_{ij}, u_{ij})\)

Step 2: Analyze the consistency of each comparison matrix by calculating the consistency index (CI) and the consistency ratio (CR):

\[
CI = \frac{\lambda_{max} - n}{n - 1}
\]

\[
CR = \frac{(CI - RI(n))}{100}\%
\]

where \(\lambda_{max}\) is the largest eigenvalue of the comparison matrix, n is the dimension of the matrix and RI(n) is a random index depending on n as shown in Table 2.

The consistency of the matrix is acceptable only if CR (10) is less than 10%. Nevertheless, the threshold of 10% can be reduced or increased depending on the tolerance of the decision makers. If a matrix results inconsistent is then necessary to obtain new pair-wise comparison judgments, determining a new pair-wise fuzzy comparison matrix to analyze. The matrix review must be continue until the consistency is obtained.

<table>
<thead>
<tr>
<th>Table 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Triangular fuzzy conversation scale</strong> (Chang, 1996; Lee, 2010).</td>
</tr>
<tr>
<td>Linguistic scale</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>JUST EQUAL</td>
</tr>
<tr>
<td>EQUALLY important</td>
</tr>
<tr>
<td>WEAKLY MORE important</td>
</tr>
<tr>
<td>MODERATELY MORE important</td>
</tr>
<tr>
<td>STRONGLY MORE important</td>
</tr>
<tr>
<td>EXTREMELY MORE important</td>
</tr>
</tbody>
</table>

The conversion scale used to convert linguistic judgments in TFNs is shown in Table 1.
Step 3: Determine the local priority weight of each criterion, sub-criterion and alternative by summing up each row of the consistent fuzzy comparison matrix \( \tilde{A} \) and then normalizing the rows to sum to 1. Finally, the crisp weights are calculated converting fuzzy weights as follows:

\[
W_i = \frac{l_i + u_i + m_i}{3} \quad \text{where} \quad \tilde{S}_i = (l_i, m_i, u_i)
\]

via normalization, the normalized crisp weight vector is:

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

Step 4: Aggregate local priority weights into global priorities:

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

is the triangular fuzzy number which expresses the linguistic judgment provided by the \( k \)-th decision maker \( k = 1, \ldots, m \) and

\[
(\tilde{a}_{ij}^{(k)})^{-1} = \left( \frac{1}{m^{l_{ij}^{(k)}}}, \frac{1}{m^{m_{ij}^{(k)} m_{ij}^{(k)}}}, \frac{1}{m^{u_{ij}^{(k)}}} \right)
\]

is the reciprocal of \( \tilde{a}_{ij}^{(k)} \). The average judgment, according to the fuzzy addition operation for TFNs (Kaufmann & Gupta, 1991) is:

\[
\overline{a}_{ij} = \frac{1}{m} \sum_{k=1}^{m} \tilde{a}_{ij}^{(k)} = \left( \frac{1}{m} \sum_{k=1}^{m} l_{ij}^{(k)}, \frac{1}{m} \sum_{k=1}^{m} m_{ij}^{(k)}, \frac{1}{m} \sum_{k=1}^{m} u_{ij}^{(k)} \right)
\]

The previous aggregate matrix is then utilized as input in the steps 1–4.

4.3. Intellectual Capital assessing criteria and hierarchical structure

In this paper, we present a Fuzzy AHP methodology to analyse IC components impact on a company value creation process. The aim of the analysis is to give guidelines to decision makers in order to create and preserve a valuable balance among IC components. Actually, many companies overlook this aspect of IC management, overinvesting in some IC components and neglecting others. The direct consequence of this lack of awareness about IC configuration is the ineffective exploitation of the company intangible assets.

An effective balance of IC components does not necessarily imply that their relative importance should be homogeneously distributed (equal weights), but it has to reflect how IC components contribute to the value creation process of intangibles (Han & Han, 2004; Wu, Tsai, Cheng, & Lai, 2006). Since each industrial sector is characterized by a peculiar knowledge value creation process, the corresponding IC configuration should change depending on the analysed industry (Costa, 2012). For this reason, we employ a Fuzzy AHP methodology to obtain the relative importance of IC components (Fuzzy AHP weights), as a clear representation of the analysed IC configuration (Bozbura, Beskese, & Kahraman, 2007; Hu, Wu, & Liu, 2012; Lee, 2010).

The proposed approach allows us to make a direct comparison between firms of the same industry in the perspective of improvement through benchmarking. In our methodology the IC configuration of a “Target” company is compared with the IC configuration of Best Practices belonging to the same industry. The choice of a sample of firms within the same business sector is essential, in order to presume that the intangible processes of value creation are similar. The benchmark, obtained through the analysis of the Best Practices, offers the Target company directions of improvement in IC management (Campisi & Costa, 2012).

Following this lead, Fuzzy AHP allows a complex decision to be structured into a hierarchy descending from an overall objective to various criteria, sub-criteria and so on until the lowest level. The objective, or the overall goal of the decision, is represented at the top level of the hierarchy. The criteria and sub-criteria contributing to the decision are represented at the intermediate levels. Finally, the decision alternatives or selection choices are laid down at the last level of the hierarchy.

The hierarchy elaborated for our analysis has the following structure (Fig. 2):

- **goal** (first level): the goal of the analysis is to assess the impact on the value creation process of the IC components. In this paper, we choose as goal the company revenue increase, meaning that the relative importance of IC components is determined on the basis of their impact on the revenue maximization. The proposed methodology is fully generalizable and it allows to choose others goals (market share, market capitalization, number of patents, etc.) depending on the value creation process of interest.
- **criteria** (second level): according to the definition of Intellectual Capital (Roos et al., 1997) there are two main perspectives of analysis: “Human Capital” and “Structural Capital”;
- **sub-criteria** (third level): according to the definition of Intellectual Capital (Roos et al., 1997) “Human Capital” has three sub-criteria: “Competence” (C1), “Attitude” (C2) and “Intellectual Agility” (C3). Also “Structural Capital” has three sub-criteria: “Relationship” (C4), “Organization” (C5) and “Renewal and Development” (C6);
- **alternatives** (fourth level): they correspond to indicators that describe the IC components and they are chosen from the existing IC measurement methods. The choice of the indicators have to comprehensively represent each component of the IC as described by Roos et al. (1997). In particular, in this paper the alternatives are represented by indicators that describe the IC components, according to the existing methodologies classified by Sveiby (2001–2010): “Training” (IND1), “Employee Motivation and Satisfaction” (IND2), “Business Climate” (IND3),
“Investments in R&D” (IND4), “Customer Satisfaction” (IND5); “Process and Product Innovation” (IND6) and “Effectiveness and Efficiency of Procedures” (IND7). The proposed methodology is fully generalizable and it allows to choose others indicators depending on the industrial sector analyzed and on the value creation process of interest.

5. An application of the Fuzzy AHP methodology to the Italian ICT service industry

We apply the proposed methodology to a “Target” company (T) belonging to the Italian Information and Communication Technology (ICT) service industry. In the perspective of improvement through benchmarking, we compare the IC configuration of the Target company to a sample of 10 companies that are Best Practices (BP) of the same industry, considering the revenue increase in the last three years (2009–2011) as the goal of the Fuzzy AHP methodology.

The characteristics of the companies under study are suitable with the purpose of this application: all IC components (Section 4.3) are significant, because they all sustain the company competitive advantage. Specifically, the Human Capital is represented by the specialized skills of ICT industry employees, while the Structural Capital is embedded in the ICT software solutions, procedures and systems and in the company network of partners, clients and suppliers. The “Target” company under study is an Italian SME, which gained its competitive position in the Italian market thanks to its ability to propose solutions for integrated ICT systems in the service industry. Until today, the Target company has been developing a sector-specific expertise, nurturing the high professionalism of its employees. We apply the Fuzzy AHP methodology to determine the prioritization of the IC components for each company and, then, we compare the IC configuration of the Best Practices with the Target one.

5.1. The Fuzzy AHP implementation

The data utilized for the Fuzzy AHP implementation are obtained interviewing managers of the analysed ICT companies: each respondent compares alternatives, sub-criteria and criteria in pairwise comparisons, expressing relative importance with linguistic terms (equally, weakly more, moderately more, strongly more, extremely more). We organize the pair-wise comparisons in a table (Table 3) in order to facilitate the respondent understanding of the questions. Then the judgments are converted in fuzzy numbers using Table 1.

As exemplification of the Fuzzy AHP procedure, we show the data and the elaboration process for the Target company. Comparing the alternatives under the criterion “Competence” (Section 4.3) by means of pair-wise linguistic judgments, we obtain the following fuzzy comparison matrix (Table 4):

Firstly, we analyse the consistency of the matrix (Section 4.2): the matrix is consistent with CI = 0.11 and CR = 0.8. Secondly, we determine the row sum \( RS_i \) (3) and the normalized row sum \( \bar{RS}_i \) (4), for each indicator (alternative) associated with a row of Table 2. The value of the row sum for the alternative “Training” (IND1), with respect to the criterion “Competence” is calculated utilizing (3) as follow:

\[
RS_1 = (1.1.1) \oplus (1.5.2.2.5) \oplus (1.1.5.2) \oplus (0.4.0.5.0.67) \\
\oplus (0.33.0.4.0.5) \oplus (0.4.0.5.0.67) \oplus \text{Bbbk}(1.5.2.2.5) \\
= (6.13; 7.9; 9.83)
\]

All the other row sum values are summarized in Table 5.

The value of the normalized row sum for “Training”, with respect to the criterion “Competence” is calculated utilizing (4) as follow:

\[
\bar{RS}_1 = \frac{RS_1}{\sum_{i=1}^{n} RS_i} \\
= \left( \frac{\sum_{i=1}^{n} lij + \sum_{k=1}^{n} lij + \sum_{j=1}^{n} m_{ij} + \sum_{i=1}^{n} m_{ij} + \sum_{i=1}^{n} n_{ij} + \sum_{i=1}^{n} n_{ij}}{\sum_{i=1}^{n} lij + \sum_{k=1}^{n} lij + \sum_{j=1}^{n} m_{ij} + \sum_{i=1}^{n} m_{ij} + \sum_{i=1}^{n} n_{ij} + \sum_{i=1}^{n} n_{ij}} \right) \\
= \left( \frac{6.13}{7.13, 7.9, 9.83} \right) = (0.0862; 0.1324; 0.195)
\]

All the other row sum values are summarized in Table 6.

Then crisp weights are calculated using (11) and, via normalization, the relative weights for each alternative under the criterion “Competences” result as:

\[
W = (0.13; 0.13; 0.11; 0.17; 0.20; 0.17; 0.09)
\]

![Fig. 2. The Fuzzy AHP model: goal, criteria, sub-criteria and alternatives.](image-url)
The same methodology is, then, applied for each item (criteria, sub-criteria and alternatives) of the structured hierarchy. The overall results for each item are obtained by multiplying their relative weights with the corresponding weights along the hierarchy (Table 7).

The same Fuzzy AHP evaluation process is replied for each Best Practice company. The average weight of criteria, sub-criteria and alternatives quantifies the IC configuration of the Best Practices, which is compared to the IC configuration of the Target company, with the purpose of improving IC management through benchmarking.

5.2. The results

Fig. 3 shows that T and BP are aligned in the IC composition, with respect to the two main IC assets: Human Capital and Structural Capital. The Human Capital is significantly more important than the Structural Capital in the value creation process, considering the revenue growth in the period 2009–2011 as the analysis goal.

This result reflects the nature of the analyzed companies: in the ICT service industry Human Resources are strategically more relevant than other organizational aspects. Human Resources are the keystone to obtain and maintain competitive advantages and IC managers often invest to enhance and emphasize human capacities within the organization (Spender & Marr, 2006). Moreover, under the “Human Capital” criterion, T follows the trend of BP; the sub-criterion “Intellectual Agility” presents the highest weight, followed by “Competence” and “Attitude” (Fig. 4).

The sub-criterion “Attitude” shows essentially the same weight both for T (22%) and BP (20%). Besides, “Competence” and “Intellectual Agility” are not aligned: the T company focuses on “Competence” more than BP (35% against BP’s 28%), while BP invests more than T in “Intellectual Agility” (52% against T’s 43%). The Target company presents an IC composition that grounds its strengths in the capacity to innovate, problem solving skills and creativity (Intellectual Agility – 43%), without neglecting competences (35%) and attitudes (22%). The IC configuration of the BP companies, chosen as benchmark for the Target firm, underlines the same composition with an evident emphasis on the innovativeness and creativity of Human Resources (Intellectual Agility – 52%). This result underlines the importance of intellectual agility as a source of competitiveness in the ICT service industry: the capacity to apply the company embedded knowledge in different business contexts, innovating and transforming ideas, is a key factor for the success of the company (Capece & Costa, 2009; Senge, 1990; Senge et al., 2000).

Under the “Structural Capital” criterion, the IC configurations of T and BP are similar: the sub-criterion “Relationship” presents the uppermost weight, followed by “Renewal and Development” and “Organization” (Fig. 5). The most aligned sub-criterion between T

\begin{table}[h]
\centering
\caption{Example of questionnaire form to compare importance of one criterion over another.}
\begin{tabular}{|c|c|c|c|c|c|c|c|c|}
\hline
With respect to “Human Capital” & Criteria & Extremely more & Strongly more & Moderately more & Weakly more & Equally & Criteria & \hline
1 & Competence & & & & & & & \hline
2 & Competence & & & & & & & \hline
3 & Attitude & & & & & & & \hline
\end{tabular}
\end{table}

\begin{table}[h]
\centering
\caption{Synthesized pair-wise judgments for alternatives with respect to the criterion “Competence”.}
\begin{tabular}{|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|}
\hline
IND1 & IND2 & IND3 & IND4 & IND5 & IND6 & IND7 & \hline
1 & 1 & 1 & 1.5 & 1 & 1.5 & 1.5 & \hline
2 & 0.4 & 0.5 & 0.67 & 1 & 1 & 1 & \hline
3 & 0.5 & 0.67 & 1 & 0.4 & 0.5 & 0.67 & \hline
4 & 1.5 & 2.5 & 1.5 & 1.5 & 2.5 & 1 & \hline
5 & 2 & 2.5 & 2 & 2.5 & 3 & 1 & \hline
6 & 2 & 2.5 & 2.5 & 2 & 2.5 & 3 & \hline
7 & 0.4 & 0.5 & 0.67 & 0.4 & 0.5 & 0.67 & \hline
\end{tabular}
\end{table}

\begin{table}[h]
\centering
\caption{Normalized row sums for each indicator with respect to the criterion “Competence”.}
\begin{tabular}{|c|c|c|c|c|c|c|c|}
\hline
IND1 & IND2 & IND3 & IND4 & IND5 & IND6 & IND7 & \hline
\end{tabular}
\end{table}

\begin{table}[h]
\centering
\caption{Synthesized pair-wise judgments for alternatives with respect to the criterion “Competence”.}
\begin{tabular}{|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|}
\hline
IND1 & IND2 & IND3 & IND4 & IND5 & IND6 & IND7 & \hline
1 & 1 & 1 & 1.5 & 2.5 & 1 & 1.5 & 1 & \hline
2 & 0.4 & 0.5 & 0.67 & 1 & 1 & 1.5 & 1 & \hline
3 & 0.5 & 0.67 & 1 & 0.4 & 0.5 & 0.67 & 1 & \hline
4 & 1.5 & 2.5 & 1.5 & 2.5 & 1 & 1.5 & 1 & \hline
5 & 2 & 2.5 & 2 & 2.5 & 3 & 1 & 1 & \hline
6 & 2 & 2.5 & 2.5 & 2 & 2.5 & 3 & 1 & \hline
7 & 0.4 & 0.5 & 0.67 & 0.4 & 0.5 & 0.67 & 0.4 & \hline
\end{tabular}
\end{table}

\begin{table}[h]
\centering
\caption{Row sums for each indicator with respect to the criterion “Competence”.}
\begin{tabular}{|c|c|c|c|c|}
\hline
IND1 & IND2 & IND3 & IND4 & IND5 & IND6 & IND7 & \hline
\end{tabular}
\end{table}

\begin{table}[h]
\centering
\caption{The overall priority weight of each criterion, sub-criterion and alternative.}
\begin{tabular}{|c|c|c|c|c|c|c|}
\hline
Criteria & Human capital 0.56 & Structural capital 0.34 & Weights & \hline
C1 & 0.33 & 0.20 & 0.47 & \hline
C2 & 0.50 & 0.18 & 0.32 & \hline
C3 & 0.11 & 0.10 & 0.18 & \hline
C4 & 0.13 & 0.11 & 0.11 & \hline
C5 & 0.17 & 0.17 & 0.17 & \hline
C6 & 0.20 & 0.22 & 0.25 & \hline
\end{tabular}
\end{table}
and BP, is “Renewal and Development” (32% for T and 30% for BP). Further, “Relationship” and “Organization” present significant differences in the relative weight: the T company focuses more on “Relationship” than BP (50% against BP’s 46%), while the BP companies favor “Organization” (24% against T’s 18%).

This IC composition is characteristic of the ICT service industry. The highest rank of the “Relationship” component reflects the importance to obtain and maintain customer loyalty and to gain a durable and reliable partnership with suppliers and distributors. The “Renewal and Development” component is only the second in the ranking of the Structural Capital components. In the ICT service industry, R&D is characterized by product and process incremental innovations: companies usually provides small changes in standardized products, customizing them without producing really radical innovations. Finally, the “Organization” component presents the lowest value, being the analyzed companies SME without a strong hierarchical structure, characterized by simplified coordination activities, routines and processes.

The indicators (alternatives) present slightly different rankings between T and BP (Fig. 6). “Customer Satisfaction” is the most significant indicator both for the T and BP companies (33% and 18% respectively) and it presents the larger gap (+15%) among indicators (Tables 8 and 9). Customer satisfaction and, as a consequence, customer loyalty are strategic assets, because in the ICT service industry customers can choose among a multitude of ICT solution providers that offer similar products and services. The other IC indicators (“Process and Product Innovation”, “R&D Investments”, “Employee Motivation”, “Business Climate” and “Training”) are quite balanced in the sample analyzed, with the exception of “Effectiveness and Efficiency of Procedures and Processes” that is the least important indicator for T, while it is the second most important aspect of BP intangibles. The low weight of T’s “Effectiveness and Efficiency of Procedures and Processes” (8%) demonstrates that the knowledge embedded in process and procedures of T is scarcer than in BP. The proportion of tacit knowledge with respect to the explicit one (contained in operative procedures) is larger in the T company, implying that T competitive advantage is hugely based on its Human Resources. This IC configuration exposes T to the risk of losing quickly its competitiveness in case of a significant turnover of its Human Resources. The gap analysis of the IC indicators underlines the main differences in the IC configuration of T and BP: “Customer Satisfaction” and “Effectiveness and Efficiency of Procedure and Processes”. Although, an IC strategic management focused on “Customer Satisfaction” is surely in line with the industrial sector under analysis, it is evident that the T company is putting too much efforts in it (see Table 9, +15% gap), neglecting the importance of maintaining the correct proportion between tacit and explicit knowledge (see Table 9, –7% gap).

Finally, the gap analysis of the other five IC indicators (Table 9) shows that the T company is aligned with BP under the other IC aspects (“Process and Product Innovation”, “R&D Investments”, “Employee Motivation”, “Business Climate” and “Training”). Nevertheless, “Employee Motivation” and “Business Climate” present small gaps (–2% and –3% respectively) underlining that the T company is less interested than BP in the welfare of Human Resources, with respect to other IC aspects.

5.3. Managerial implications

The presented Fuzzy AHP methodology offers guidelines to managers for improving the balance among IC components, regarding their impact on the company value creation process. The Fuzzy AHP approach prescribes the direct comparison between the T company and a sample of BP belonging to the same industry, in the perspective of improvement through benchmarking. Indeed, an effective balance of IC components has to reflect how they contribute to business performance, making essential the choice of the sample within the same business sector, in order to presume that the IC value creation process is similar.

In our methodology the BP configuration of intangible assets constitutes the benchmark that the Target has to follow in order to maximize the efficiency of its IC management. The results of the analysis highlight that the relative importance of the IC components of T and BP presents some relevant differences. The T company should develop IC strategies less focused on “Relationship” and “Customer Satisfaction”, and more centered on “Organization” and “Effectiveness and Efficiency of Procedures and Processes”. Moreover, the T company should put more efforts in enhancing the “Intellectual Agility” of its Human Resources, without relying too much on their “Competence”. The gap analysis of the IC
component weights demonstrates that T gives too much importance to its relationship with customers, overlooking to improve the soundness of its procedures and processes. Moreover, T also underestimates the value of the intellectual agility as a source of competitiveness in the ICT service industry. Actually, the capacity to apply the company embedded knowledge in different business contexts (intellectual agility) is strategically connected with the reliability of the company procedures and processes (Calabrese, 2012; Calabrese & Scoglio, 2012). In this case, the tacit knowledge in the organization is too high compared with the explicit one and there are not adequate efforts in creating an organized explicit knowledge repository that is continuously fed and leveraged. The T company should favor knowledge sharing activities and the structurization and formalization of capabilities, in order to enhance problem solving, creativity and innovativeness in the organization. Moreover, a more collaborative environment should improve business climate and employee motivation (Calabrese, Costa, Menichini, Rosati, & Sanfelice, 2013).

The proposed methodology should be repeated regularly in order to monitor possible shifts in the configuration of the IC components, analyzing how IC investments are related to business performance.

6. Conclusions

In this paper, we present a Fuzzy AHP methodology to analyse the impact of IC components on a company value creation process. The aim of the analysis is to provide guidelines to decision makers in order to create and preserve a valuable balance among IC components. Actually, many companies overlook this aspect of IC management, overinvesting in some IC components and neglecting other ones. The direct consequence of this lack of awareness about IC configuration is the ineffective exploitation of the company intangible assets. Following this lead, the purpose of the proposed methodology is to determine which IC investments should be reduced and which ones should be increased in order to improve a company business performance. We suggest to balance IC components by applying a benchmarking approach: a company, called Target, is compared to Best Practices of the same industry with respect to the configuration of their IC components.

We choose Fuzzy AHP to determine the ranking (or relative importance) of the IC components, because, as an extension of the classic AHP method, it considers the fuzziness and vagueness of the linguistic judgments expressed by decision makers about the impact of the IC components on business performance. Nonetheless the existence of a large number of methods to handle Fuzzy AHP, we present an innovative approach to determine the relative importance of IC components, which starts from a review of Chang’s extent analysis method (1996).

Finally, we apply the proposed Fuzzy AHP approach to a sample of companies operating in the ICT services industry. The presented methodology is a useful tool to support decision makers in managing IC investments, selecting which IC components should be leveraged to improve performance. Actually, the outcomes of the application offer direction for progress, that should constitute the basis for the formulation of future IC strategies.
References


