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**Volume 1**

**Edited by**

**Carla Vivas and Pedro Sequeira**



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**Volume One**

**Edited by  
Dr Carla Vivas and Dr Pedro Sequeira**

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# Designing and Testing an AHP Methodology to Prioritize Critical IC Elements for Product Innovation

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**Abstract:** Intellectual capital has for the past decades been evidenced as an important source of competitive advantages and differentiation at the firm level. At the same time, innovation has become a critical factor for companies to ensure their sustainability and even their survival in a globalized market. Having in mind these two crucial concepts for business success, this study intends to build on the relationships between intellectual capital and product innovation at the firm level. Specifically, we will design and test a model based on the Analytic Hierarchy Process (AHP), whose aim is to allow the prioritization of intellectual capital elements according to their relative importance for product innovation performance at the firm level. The main goal of this research is to build a diagnosis and action tool that helps business managers incorporate an intellectual capital perspective to their product innovation initiatives. This framework will help managers to better understand which intellectual capital elements are more critical to their product innovation efforts, and thereby systematize actions and clarify resource allocation priorities to improve their product innovation capabilities. In order to validate the practicability of this proposal, the methodology was empirically applied to a Portuguese innovative small and medium enterprise (SME).

**Keywords:** intellectual capital, product innovation, analytic hierarchy process, Portugal, AHP, SMEs

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## 1. Introduction

Competitiveness is nowadays a key concern for nearly every firm, maybe more than ever. The business landscape has for the past years become more and more demanding, with a widespread economic and financial crisis adding to an already challenging environment, shaped by complex structural trends such as globalization, technological evolution, accelerated product cycles and rapid changes in consumers' needs and expectations (Daneels, 2002).

Against this backdrop, two critical factors for the competitiveness of firms assume particular relevance: intellectual capital (IC) and innovation.

In fact, as the "resource-based view of the firm" stream of research began to highlight (Barney, 1991; Wernerfelt, 1984), resources and competencies of intangible characteristics, as opposed to the traditional "land, labour and financial capital", have gradually emerged as critical success factors to corporations. It is now abundantly clear that intangible assets are driving value creation in today's global economy (Dumay and Garanina, 2013; OECD, 2012).

At the same time, innovation has become one of the most crucial drivers of long term development (Leiponen, 2005; Lederman, 2010). At the firm level, innovation is a key aspect for business success in the current competitive arena, representing one of the best ways for reaching competitive advantages (Delgado-Verde et al., 2011).

As we will argue in our literature review section, several studies have linked intangible assets, and IC in particular, to the firms' ability to innovate. It thus seems especially relevant for managers to be able to analyse and manage this relationship, so that actions can be taken and strategies corrected in order to develop and improve the firm's innovation capabilities. The main goal of this article is thus to try to address this need. Specifically, we will design and test a model to allow the prioritization of IC elements according to their relative importance to product innovation success at the firm level.

The structure of the paper is as follows: the following section proposes a brief review of the literature regarding IC, product innovation, the relationships between those concepts, and the benefits of measuring IC. The next section presents our proposed methodology to prioritize IC indicators for product innovation performance, using AHP. We will then describe the application of the model within a SME. Finally, some insights and conclusions will be extracted and discussed.

## **2. Literature review**

### **2.1 Intellectual capital**

Research on IC gained steam in the mid-nineties as a natural corollary of the resource and knowledge-based views of the firm. The aim was to understand the implications of those theories for the daily management of corporations, through the analysis of the intangible assets' contribution to an organization (Roos et al., 2001). Descriptions of IC abound in the literature, although there isn't yet a clear, internationally accepted single definition. For the purpose of this study, we will thus define IC as "the stocks or funds of knowledge, intangible assets, and ultimately intangible resources and capabilities, which allow for the development of basic business processes of organizations, enabling the achievement of competitive advantages" (Martín-de-Castro et al., 2011, pp. 650). IC is thus a multidimensional concept. It is nowadays generally accepted that the main components of IC can be structured into three dimensions: human capital, structural capital and relational capital (Guthrie et al., 2012).

Human capital represents those intangible resources that are linked to the individual and generate value to the company. Human capital includes such diverse elements as individual values and attitudes, aptitudes, and know-how (Subramaniam and Youndt, 2005).

Structural capital is the knowledge that the company has managed to internalize and that remains in the organisation, either in its structure, its processes or its culture, even when the employees leave. Bueno & Salmador (2000) refer to structural capital as the systematized and explicit knowledge that has been internalized by the organisation, such as its values, culture, routines, protocols, procedures, systems, technological breakthroughs and intellectual property. In other words, it refers to the organisation's intelligence, which, unlike human capital, belongs in fact to the company.

The relational capital concept is based on the consciousness that companies are actively and permanently connected to multiple external entities. All valuable relationships of this kind, with customers, suppliers and other relevant stakeholders, represent relational capital (Roos et al. 2001).

### **2.2 Product innovation**

Innovation is in the core of economic change, and its role as the main driver of long term development is today widely acknowledged (Leiponen, 2005). Both at the macro and at the micro level, policies focused on employment creation and social welfare have been aiming at strengthening the innovative ability of enterprises and regions to enhance their competitiveness (Bullinger et al., 2004). At the firm level, innovation is nowadays considered to be inevitable. To succeed in today's complex economic environment, or even to remain viable, corporations must respond with innovation (Govindarajan and Trimble, 2005).

In the Oslo Manual (OECD, 2005), different types of innovations are distinguished: product innovations, process innovations, marketing innovations and organisational innovations. Among these distinct types of innovations, product innovation stands out as an element of particular importance to any business. Companies must develop new products, at least on occasion, to maintain or gain competitive advantages, and their ability to create new products has been linked to performance and even long-term survival (De Jong and Vermeulen, 2006; Linzalone, 2008). This study will therefore focus on product innovation.

### **2.3 Relationships between IC and product innovation**

The relationship between intangible assets and innovation has been analysed in several empirical studies, generally concluding that intangible assets are positively and significantly associated with the firms' innovative capabilities. For example, Cañibano et al. (2002) found that innovative, technology-intensive companies are typically those where intangible assets assume a more critical role. Del Canto and Gonzalez (1999) argue that intangible resources have a decisive impact on the "absorption" ability of firms, that is, on their ability to recognize and exploit opportunities abroad, and also on their "transformation" ability, meaning the aptitude to continuously redefine their product portfolios based on the opportunities created within the company. The European Commission (2006) contends that there are strong links and contingencies between research and development, innovation, human capital and relational capital. Other studies state that firm-level knowledge is



associated with a higher degree of innovation (Thornhill, 2006; Bueno et al., 2010), and that knowledge assets can play a critical role in the different phases of the NPD process (Linzone, 2008).

The specific analysis of the relationship between IC and product innovation is scarcer. However, some recent studies have shown that the distinct components of IC (human capital, structural capital and relational capital), either individually or combined, have a significant positive relationship with the outcomes of product innovation efforts at the firm level (Chen et al., 2006; Costa et al., 2011; Delgado-Verde, 2011; Dorrego et al., 2013; Fernandez-Jardón et al., 2014; Hsu and Fang, 2009; Santos Rodrigues et al., 2010; Subramanian, 2012; Subramanian and Youndt, 2005; Wu et al., 2008).

## **2.4 Measuring intellectual capital**

According to Marr (2004), organizations measure IC for different reasons: to formulate and assess strategy; to influence people's behaviour; and to externally validate performance, which includes reporting and benchmarking. The European Commission (2006) argues that as the future potential of an enterprise lies not within its financial capital but in its IC, measuring the enterprise's IC will enable it to manage its intangible resources better and increase its staff's confidence and motivation. An IC framework will function as an internal navigation tool to help develop and allocate resources – create strategy, prioritise challenges, monitor the development of results and thus facilitate decision-making. Chiocchi (2008) also notes that the implementation of an IC measurement system positively affects managerial competences since the analysis of company drivers and cause and effect relationships not only increases the understanding of the business but it also improves the quality of the company management, making it more rational and professional. According to Sveiby (2010), the most interesting reason for measuring intangibles is the learning motive.

The increasing awareness of the benefits of measuring and managing IC is reflected in the growing number of its measurement frameworks (Marr, 2004). In fact, Sveiby (2010) identifies over 40 models or frameworks that cover both the financial and non-financial measures of IC. However, none of those models actually tries to assess the drivers of intangible value creation within a product innovation context. Just as Yu and Humphreys (2013) state that measuring IC constitutes a learning process and an experience that enhances a firm's future earnings potential, we argue that measuring and managing IC within a product innovation context can enhance the firm's ability to successfully launch new products and services, and thus become more competitive and profitable. Yet, most companies do not identify core IC indicators in many areas that directly influence business value, and those that do frequently use them in an inefficient manner (Kim and Kumar, 2009). The remaining of this article tries to address this issue, by offering some clues regarding the possibilities of modelling and prioritizing IC indicators within a product innovation context.

## **3. A methodology to prioritize critical IC elements**

Having argued that product innovation is a key source of competitiveness and that IC can decisively influence its success, it is only natural for us to stress that these two concepts and their relationships cannot be ignored by business managers. Moreover, they should be measured and managed carefully.

### **3.1 The AHP method**

The AHP analysis, proposed by Saaty (2008), is a pair-wise comparison methodology that results in breaking down a complex problem and then combining the solutions. It has been broadly acknowledged that the AHP analysis is one of the best methodologies to prioritize various indicators. Furthermore, the AHP approach needs only a small number of respondents with experience and knowledge (Kim and Kumar, 2009).

The basic principle of this tool lies in analyzing several alternatives from different criteria. Thus, a hierarchy is built, where at the top is the problem to be taken into consideration. The next layer consists in the criteria or strategies to be considered; and the last layer resides in several alternative activities or actions (for each of the criteria from the second level).

Based on comparative judgments, a positive matrix of choices is derived from these criteria. A ranking structure is achieved afterwards as a vector of priorities, based on the theory of eigenvectors. The same procedure is applied for the alternatives considered with respect to every criterion. Then, weights beard by the criteria are applied to the considered alternatives and lastly, the corresponding totals for each alternative are



calculated. Within the very abstract and fuzzy framework of IC, the step by step approach provided by AHP, breaking down the problem into smaller parts that can be more easily handled, represents an important advantage.

The first level of our proposed hierarchical structure encompasses the organization's goal (in our specific case, maximizing product innovation performance through the identification and management of critical IC elements). Second level variables are the basic IC components (human capital, structural capital and relational capital), as vital drivers of product innovation performance; the particular intangible elements that refer to each second level component are grouped in third level variables, which are those IC elements considered to be more critical to product innovation success. At the last level, the specific indicators for each IC element are provided. For this purpose, we used the indicators and structure suggested by Costa et al. (2011), Dorrego et al. (2013) and Fernandez-Jardón et al. (2014). Table 1 presents our suggested hierarchical structure.

**Table 1:** The AHP model hierarchy: critical IC elements for product innovation

1 <sup>st</sup> Level: organization's goal		
Maximizing product innovation performance through the identification and management of critical IC elements		
2 <sup>nd</sup> Level: IC components	3 <sup>rd</sup> Level: critical IC elements	4 <sup>th</sup> level: specific indicators
Human Capital	Competencies	<ul style="list-style-type: none"> <li>*Top managers and technical staff possess high education levels and specialized training</li> <li>*Top managers and technical staff possess professional experience in different activities</li> <li>*Top managers and technical staff possess (among them) an heterogeneous academic education</li> <li>*Employees possess specific competencies that are adequate to the firm's product innovation goals</li> </ul>
	Values and attitudes	<ul style="list-style-type: none"> <li>*Employees cooperate and share knowledge</li> <li>*Employees take risks, are enterprising and creative</li> <li>*Employees show interest and participate on idea generation activities</li> <li>*Employees are committed to the firm's strategy</li> </ul>
	Capabilities	<ul style="list-style-type: none"> <li>*Employees participate on training initiatives related to innovation and successfully apply the knowledge they acquire</li> <li>*Employees often develop team work</li> <li>*Leaders strive to communicate the role of innovation on the firm's strategy</li> <li>*Employees know and understand the firm's new product development process</li> </ul>
Structural Capital	Corporate culture towards innovation	<ul style="list-style-type: none"> <li>*There is a new product ideas scheme in place, and employees are encouraged to participate (for instance through economic incentives)</li> <li>*Entrepreneurs and innovative project leaders are encouraged and rewarded, with no punishment for failures</li> <li>*Employees have autonomy and resources to develop their creativity through informal and parallel projects</li> </ul>
	Top management role	<ul style="list-style-type: none"> <li>*Innovation metrics represent an explicit and important part of top management's performance evaluation</li> <li>*Top management is strongly committed to the product innovation process</li> <li>*Top management provides clear support, autonomy and authority to the people involved in product innovation projects</li> </ul>
	Strategy and innovation	<ul style="list-style-type: none"> <li>*The role of innovation in achieving the firm's strategic goals is clearly defined</li> <li>*There is a plan to identify/acquire the skills that are necessary to achieve product innovation goals</li> <li>*The areas of strategic focus on which to concentrate the product innovation efforts are clearly identified</li> <li>*The role of innovation in achieving the firm's strategic goals is clearly defined</li> </ul>
	NPD management	<ul style="list-style-type: none"> <li>*The characteristics of project teams are a very important feature of the product innovation process</li> <li>*There is a system to manage new product development projects</li> <li>*There is a well organised new product development process</li> </ul>

1 <sup>st</sup> Level: organization's goal Maximizing product innovation performance through the identification and management of critical IC elements		
Relational  Capital	Vertical and horizontal relationships	*There are vertical relationships (with customers and suppliers) with the specific goal of strengthening our product innovation capabilities *There are horizontal relationships (with partners and competitors) with the specific goal of strengthening our product innovation capabilities *There are relationships with other institutions (government agencies, external experts, public and private R&D centres, shareholders, etc.) with the specific goal of strengthening our product innovation capabilities
	Management of relationship processes	*The company makes a specific effort to identify and establish relationships with customers or users who are more receptive to innovative products (lead users) *The company actively manages formalized relationship processes with clients *The company actively manages formalized relationship processes with suppliers *The company actively manages formalized relationship processes with competitors *The company actively manages formalized relationship processes with institutions, shareholders and investors

The next step is to compare the relative importance of components. For that purpose a questionnaire must be built, pairing components, elements and indicators, questioning which of each pair is more important with regards to the objective, and how much more important. In order to help the respondent to assess the pair-wise comparisons, Saaty created a nine point intensity scale of importance between two elements (Saaty, 2008). The suggested numbers to express degree of preference between the two elements A and B are shown in Table 2.

**Table 2:** The fundamental scale for pair-wise comparisons (Saaty, 2008)

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one activity over another
5	Strong importance	Experience and judgment strongly favor one activity over another
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	For compromise between the above values	Sometimes one needs to interpolate a compromise judgment numerically because there is no good word to describe it

The questionnaire is then built and presented to respondents. Next is an example of the pair-wise questionnaire for level 2 IC components:

Level 2 – IC Components:

How important is “ <b>Human Capital</b> ” when compared to “ <b>Strutural Capital</b> ”?																	
<b>Q1</b>	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9
How important is “ <b>Human Capital</b> ” when compared to “ <b>Relational Capital</b> ”?																	
<b>Q2</b>	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9
How important is “ <b>Strutural Capital</b> ” when compared to “ <b>Relational Capital</b> ”?																	
<b>Q3</b>	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

The next step, the calculation of relative weights based on the answers to our questionnaire, is conducted using Microsoft Excel. As previous research suggested (Saaty, 2008), three steps are employed. They are:

- (a) Using questionnaire results to insert the data in Excel, building binary comparison matrices for each level of the hierarchical structure;
- (b) Calculating relative weights:
  - (b.1) Sum of each column of the matrix;

(b.2) Dividing each element of the matrix by the sum of the corresponding column, obtaining a new standardized matrix;

(b.3) Calculating the average of each line of the standardized matrix (sum and divide by n variables considered), obtaining the column vector “w” (relative weight). The sum of the vector must equal 1;

(c) Verifying matrix consistency:

(c.1) Multiplying the sum of each column of the original matrix (step b.1) by vector “w” (step b.3), obtaining a new vector (consistency measure);

(c.2) If the matrix is consistent, the vector calculated in step c.1 will have values ideally equal to 1.

### 3.2 Testing the AHP methodology: Empirical results

In this section, the implementation of our proposed model is demonstrated on a real firm, a Portuguese innovative SME. The firm is located in northern Portugal and operates in the chemical industry. Creating innovative products is one of its core strategic aims. It has around 100 employees and an annual turnover estimated at €72 million. The questionnaire was presented to the firm’s CEO, as suggested by the Oslo Manual (OECD, 2005), since he represents the key informant that better knows the subject of the research and who is most available to communicate it to the researcher. From the interview and presentation of our questionnaire it became apparent that the interviewee generally understood the concept of IC, recognizing its importance to the company’s product innovation performance. This study was labelled as very pertinent, as he recognized the interest to build a model that in an intuitive way depicts the relative importance of each IC element to the firm’s innovation strategy. Regarding the actual results from the completion of the questionnaire, we will now present some partial outcomes, including level 2 IC components, level 3 elements for human capital and level 4 indicators for the human capital element “Competencies”:

#### Level 2 – IC Components:

Original matrix:

	HC	SC	RC
HC	1	4	1
SC	0,25	1	0,33
RC	1	3	1
Sum:	2,250	8,000	2,333

HC – Human Capital  
SC – Structural Capital  
RC – Relational Capital

Standardized matrix:

	HC	SC	RC
HC	0,444	0,500	0,429
SC	0,111	0,125	0,143
RC	0,444	0,375	0,429
Sum:	1,000	1,000	1,000

w	CM
0,458	1,030
0,126	1,011
<u>0,416</u>	0,971
1,000	

(w=relative weight; CM=consistency measure)

#### Level 3 - Human capital elements:

Original matrix:

	Comp	V&A	Cap
Comp	1	0,25	0,25
V&A	4	1	1
Cap	4	1	1
Sum:	9,000	2,250	2,250

Comp – Competencies  
V&A – Values and Attitudes  
Cap – Capabilities

Standardized matrix:

	Comp	V&A	Cap
Comp	0,111	0,111	0,111
V&A	0,444	0,444	0,444
Cap	0,444	0,444	0,444
Sum:	1,000	1,000	1,000

w	CM
0,111	1,000
0,444	1,000
<u>0,444</u>	1,000
1,000	

(w=relative weight; CM=consistency measure)

**Level 4 - Indicators for human capital element "Competencies":**

Original matrix:

	ELST	PE	HAE	SC
ELST	1	3	4	1
PE	0,33	1	1	0,33
HAE	0,25	1	1	0,33
SC	1	3	3	1
Sum:	2,583	8,000	9,000	2,667

ELST – Education levels and specialized training

PE – Professional experience

HAE – Heterogeneous academic education

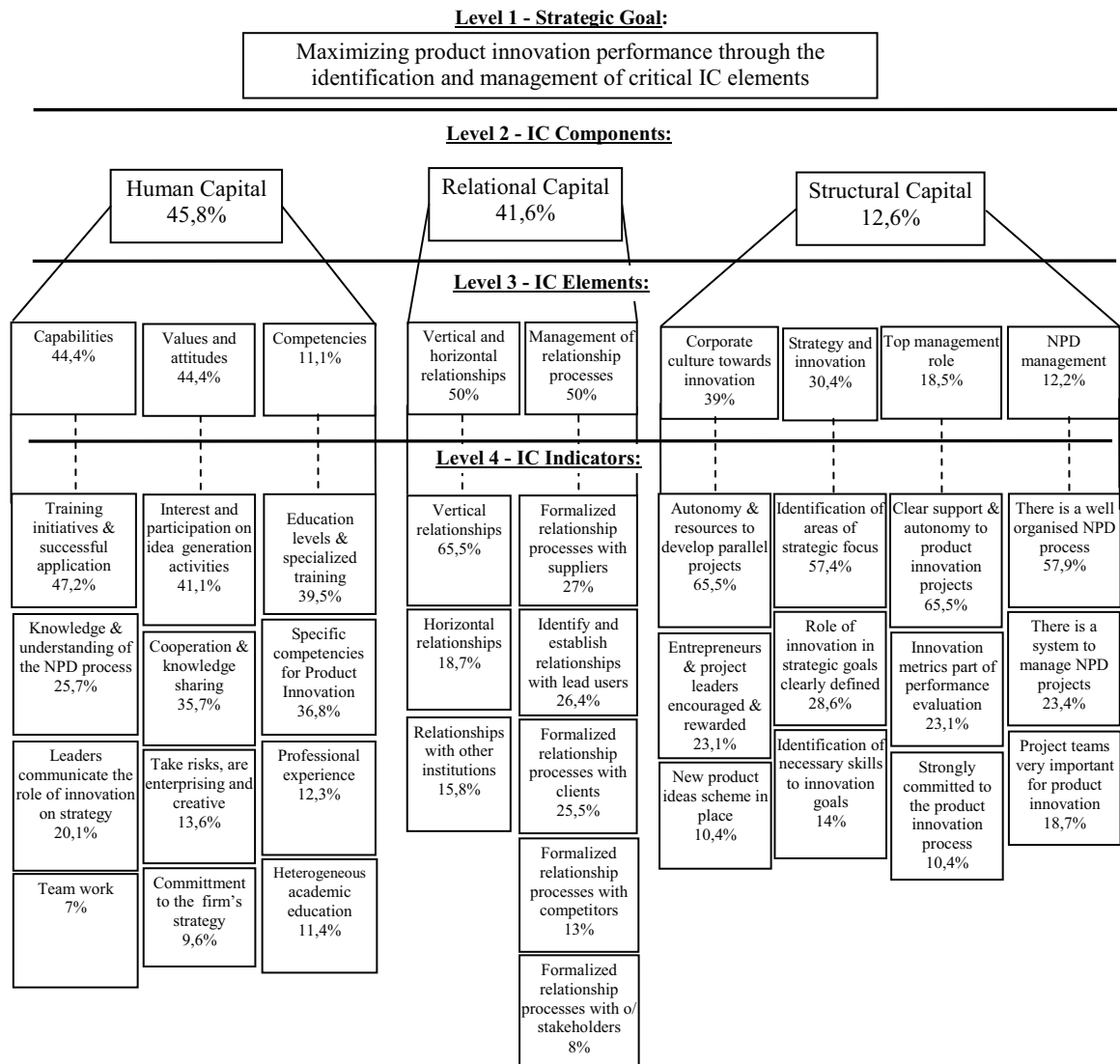
SC – Specific competencies for product innovation

Standardized matrix:

	ELST	PE	HAE	SC	w	CM
ELST	0,387	0,375	0,444	0,375	0,395	1,021
PE	0,129	0,125	0,111	0,125	0,123	0,980
HAE	0,097	0,125	0,111	0,125	0,114	1,030
SC	0,387	0,375	0,333	0,375	0,368	0,980
Sum:	1,000	1,000	1,000	1,000	1,000	

(w=relative weight; CM=consistency measure)

After applying the same process to all levels, we were able to depict the final results using our original hierarchical structure, as shown in Figure 1:



**Figure 1:** An application of the AHP model hierarchy

This map depicts the hierarchization of all critical IC components, elements and particular indicators in what concerns their importance to product innovation success, as per the perception of the firm's CEO. We can see for example that human capital is considered to be the most important IC component, as opposed to structural capital which ranked as the least important; the elements 'capabilities' and 'values and attitudes' assume equal importance within the human capital component; the most valued specific human capital items are 'training initiatives and their successful application', 'interest and participation on idea generation activities' and 'education levels and specialized training'.

Building on Kim and Kumar's (2009) proposal, from this results we can put together a second map oriented to the practical envisage of the prioritized elements from an operational perspective. Figure 2 shows which areas should be subject to a more careful and urgent attention (core focus areas), helping the firm to visualize more intuitively the specific IC elements where it should focus its resources and efforts, in order to improve its product innovation performance.

The empirical testing of the proposed AHP methodology was thus, in our opinion, very successful, fully meeting the goals that were initially set. Not only the company acknowledged its interest and understood its variables and modus operandi without major difficulties, but also the handling of the responses allowed the construction of a preference hierarchy and the identification of focus areas, which was recognized as meaningful and useful for the company's product innovation strategy.

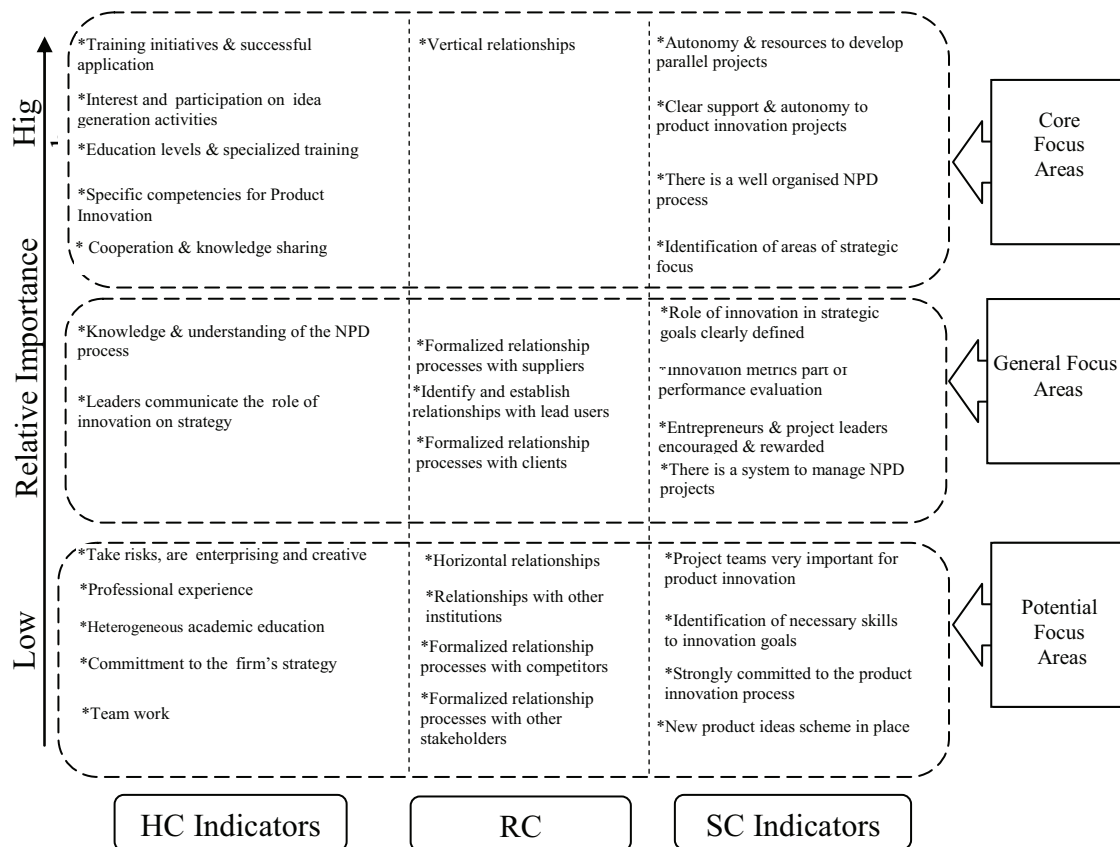


Figure 3: Focus areas for IC development towards product innovation success

#### 4. Conclusions

In today's competitive environment, product innovation should be regarded as a priority by any business. However, firms in general and SMEs in particular are confronted with two paradoxical issues when it comes to innovation: intensify innovation efforts to develop new products, and in doing so, become more vulnerable by engaging in projects characterized by very high levels of risk. Indeed, product innovation projects are very risky in nature since, generally, they take more time than expected, cost more material resources than those planned, and do not always produce the anticipated benefits with respect to performance. SMEs are particularly vulnerable to this dilemma, as the typical scarcity of resources at their disposal dramatically

reduces their margin of error (Rhaïem, 2012). At a time when there is growing evidence of IC's relevance for product innovation performance, this dilemma strongly reinforces the importance of IC management as a means to increase the odds of product innovation success at SMEs.

Against this backdrop, this research aimed to design a diagnosis and action tool to help business managers incorporate an intellectual capital perspective into their product innovation efforts. We understand our proposal as a relevant contribution for both the literature and practice of IC and product innovation, as it stresses the importance of identifying and prioritizing those intangible elements that are decisive to the success of product innovation initiatives at SMEs. In fact, the proposed AHP methodology represents a particularly effective way of conducting this process, ultimately allowing managers to concentrate on the most critical factors that drive product innovation within their firm. Additionally, we cannot forget that accepting the importance of IC and embracing it as a management priority is the final result of a learning process that involves talking about IC, understanding its contribution to the value creation process, thinking about how and when it impacts corporate phenomena - that is, "the pragmatic dimension" of IC (Giuliani and Marasca, 2011). The implementation of this methodology can also contribute to this learning path, as it will inevitably trigger a brainstorming process regarding IC inside the firm, ultimately helping it to develop a better understanding of how distinct IC elements impact its product innovation efforts. The authors acknowledge that this paper has a few limitations and possibilities for future research. In fact, although the framework is conceptually applicable to any firm, the effectiveness of the methodology was tested in only one SME. In order to generalize the findings, future research should test the model validity on a representative sample, ideally in different industries and even countries.

We should also stress that our main goal was not to develop a standardized IC model, but to propose a methodology that can help managers systematize and prioritize critical IC elements that are suitable for their particular reality. In fact, although we admit that identifying standardized indicators could help many organizations understand the importance of IC management within their product innovation strategy, IC is ultimately firm-specific and closely tied to the organization. Therefore, our proposed IC variables must be understood as a starting point, which can (and should) be subject to adaptations depending on the reality of each firm.

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