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THE RELEVANCE OF INTELLECTUAL CAPITAL STATEMENT AS A GROUNDWORK FOR INDUSTRY 4.0

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Abstract. *The fourth industrial revolution is profoundly changing the basis of competitive advantage from tangible to intangible resources. The survival and growth of a company depends on how it develops its intellectual capital. However, little attention is observed in the literature regarding intangible assets. This research aimed to develop a conceptual framework that supports industries to assess and cultivate their intellectual capital to prepare for adopting new technologies related to Industry 4.0. It was developed based on the European Intellectual Capital Statement model. Adjustments were made to this model, emphasizing among them the insertion of lessons learned from manufacturing companies that have already adopted Industry 4.0. A pilot project was conducted, evaluating the applicability of the proposed method in a Brazilian manufacturing company. As a result, it was possible to identify a perception of higher value by the company of its own human capital, followed by its structural and relational capital. The action plan developed by the company resulted to be closer to the best practices observed in the process of adopting Industry 4.0 technologies, indicating that the proposed framework serves industries to evaluate and develop their intellectual capital, nurturing their intangible assets as a tool to prepare companies to adopt Industry 4.0 technologies.*

Keywords: *Industry 4.0, Intellectual Capital Statement, Smart Manufacturing, Smart Working*

1. INTRODUCTION

The Fourth Industrial Revolution is based on the digital revolution, transforming society and the global economy (Schwab, 2016). Digitalization is a phenomenon that affects all industries, where many traditional products are being replaced by similar digital ones, or at least being equipped with digital functionalities. However, digital transformation goes far beyond product and process improvement. It also affects business models, organizational and managerial aspects, and all processes in value chains, thus creating significant challenges for companies. Digitization affects not only physical products, but also the nature of business, organizational structures, and strategies (Horváth and Szabó, 2019).

Industry 4.0, a new manufacturing paradigm, refers to the digitization and connection of the industrial value creation process (Ghobakhloo, 2018 and Kagermann *et al.*, 2013). According to Mahmood and Mubarak (2020), researchers and practitioners consider that Industry 4.0 empowers companies to increase their operational efficiency and innovate faster. Ahmed *et al.* (2019) and Mubarak (2015) report that the fourth industrial revolution is profoundly changing the basis of competitive advantage from tangible to intangible assets. In this sense, for an organization's success, it is vital that tacit resources and knowledge are developed and acquired, thus obtaining both greater operational efficiency and competitiveness (Mahmood and Mubarak, 2020). However, little attention in the literature is observed with regard to intangible assets.

In such a context, a successful transformation to Industry 4.0 requires organizations to re-examine their strategy for approaching Intellectual Capital (IC) (Mahmood and Mubarak, 2020). IC stands by the study of the roots of a company's value, the measurement of the hidden dynamic factors that underlie the visible company of buildings and products (Edvinsson and Malone, 1997). Only a few authors have made examinations on how IC is related to Industry 4.0 (see e.g.

Mahmood and Mubarik, 2020). There is also a lack of studies providing empirical evidence about the way Industry 4.0 is adopted in manufacturing companies (Veile *et al.*, 2018; Frank, Dalegonare and Ayala, 2019; Horváth and Szabó, 2019), leading to an important question: **“is it possible to support manufacturing companies to adopt Industry 4.0 by developing their intellectual capital?”**

To answer this research question, an Intellectual Capital Statement model was adapted, considering lessons learned from German companies that have successfully adopted Industry 4.0. The adapted model was applied in a pilot project with a medium-sized manufacturing company belonging to the auto parts value chain. Finally, the results were analyzed and discussed. This contribution is in line with the suggestions of the study by Meindl *et al.* (2021), in which, when analyzing ten years of publications on the topic "Industry 4.0", the authors found that the “Smart Working” dimension is the least explored, with many opportunities for future research. This dimension considers how Industry 4.0 technologies are used to support company workers in their activities, considering how to extract the best from their creative work and decision-making potential, thus increasing their satisfaction and safety in the work environment.

This paper has been divided into five sections. Section 2 provides a conceptualization of Industry 4.0 on the socio-technical perspective. In this same section, it is presented the concepts of Intellectual Capital Statement, as well as their importance for the development of intangible resources for manufacturing companies. Section 3 highlights the methodology used to develop the adaptation of the Intellectual Capital Statement in the context of Industry 4.0. The main results and findings are discussed on Section 4. Finally, Section 5 presents the conclusions and implications of the study.

2. THEORETICAL BACKGROUND

Industry 4.0 is both a technological and a socioeconomic phenomenon (Horváth and Szabó, 2019). According to Garcia and Alvarado (2013), technologies related to advanced manufacturing are considered a socio-technical system. According to Sony and Naik (2020), Industry 4.0 is a socio-technical system, which contains social (human) and technical (non-human) aspects that will interact in order to pursue a common goal. Therefore, the success of Industry 4.0 will be a composite function of technical feasibility and social acceptance of the entire digital transformation process (Horváth and Szabó, 2019). In a complementary way, Sony and Naik (2020) argue that the success of Industry 4.0 implementations and sustainability depend on evaluating the relationships of the social and technical aspects of a project.

Thus, this section presents the state of the art of both the social and technical aspects of Industry 4.0, unfolding its characteristics, tensions, and opportunities in the social and technological context. Furthermore, it addresses, in a complementary manner, the concepts related to the Intellectual Capital Statement. At the end of this section, a synthesis of the main characteristics, gaps, and opportunities for complementarity between the concepts is presented.

2.1 Industry 4.0 as a socio-technical system

According to Schuh *et al.* (2017), while advanced technologies enable access to a much wider range of data, the ability to harness the underlying potential of that data is dependent on organizational structure and culture. The ultimate goal is to develop a learning and agile enterprise that is able to provide continuity, agility, and adaptation to a changing environment. In fact, the main potential in the transition of companies to advanced manufacturing lies in the ability to accelerate the decision-making processes in manufacturing and corporate adaptation to the business environment. This applies both to promoting efficiency in engineering, manufacturing, service, sales and marketing processes, as well as to the focus of companies' businesses, with consequences for their business models (Brasil, 2017).

According to Morrar, Arman, and Mousa (2017), Industry 4.0 enables the transformation of modern economies to become more innovative and, as a result, to become more productive. The use of technologies such as the industrial internet, smart systems and digital chains is expected to accelerate innovations, which enable a faster implementation of new business models. Industry 4.0, therefore, increases the perception of the consumer's contribution as a co-producer and places him or her at the center of all activities. According to Morrar, Arman, and Mousa (2017), **Industry 4.0 places the human being at the center of production**. It becomes necessary to establish interactive relationships with customers in order to identify and fully meet their needs.

In this new industrial revolution, traditional competitiveness factors such as market share, economies of scale, and access to resources are now connected with other factors such as innovation, intellectual property rights, advanced technologies, and access to knowledge. Industry 4.0 represents a shift toward an innovation-driven economy, with knowledge, data, and the internet of things as central concepts. Innovative solutions can both support companies to improve their existing processes, as well as develop new business models (Morrar, Arman and Mousa, 2017).

2.2 Industry 4.0 in the context of its base technologies

According to Frank, Dalenogare and Ayala (2019), Industry 4.0 technologies can be classified into at least two layers, Base Technologies and Front-End Technologies, as proposed in the conceptual framework presented in Figure 1. According to Meindl *et al.* (2021), this conceptual framework, proposed by Frank, Dalenogare and Ayala (2019), is one of the most frequently cited in the academic literature.

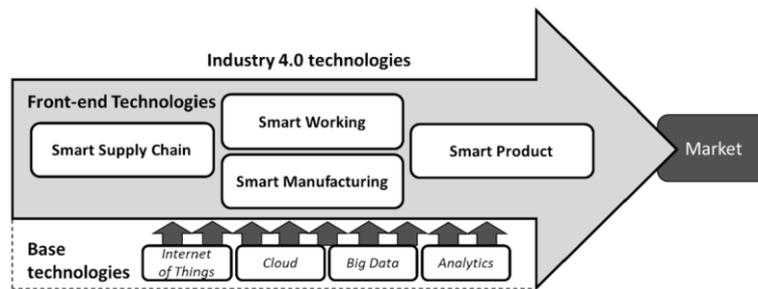


Figure 1. Theoretical framework of Industry 4.0 technologies (Frank, Dalenogare and Ayala, 2019).

According to Frank, Dalenogare, and Ayala (2019), the Base Technologies are composed by four elements - Internet of Things, Cloud Computing, Big Data, and Data Analytics – that have different capabilities. The internet of things allows solving connectivity problems between all objects and systems in a factory, while cloud computing allows easy access to information and services. Big data and data analytics are considered as enabling technologies for advanced Industry 4.0 applications, since the intelligence of a system depends on the accumulation of big data and the ability to analyze it through advanced techniques (analytics).

2.3 Lessons Learned of Industry 4.0 adoption process

Considering the scarcity of empirical studies that could substantiate Industry 4.0 practices, it was adopted the lessons learned identified by Veile *et al.* (2019), through an empirical study conducted with 13 German industrial companies, summarized and presented in Table 1, as the basis for the proposed method developed and applied in this paper.

Table 1. Main Lessons learned identified by Veile *et al.* (2019)

Dimensions	Main Lessons Learned
1- Corporate Culture & communication	- Promotion of a creative environment, which drives idea generation and tolerance for error, through democratic leadership; - Corporate culture should always focus on the customers and their demands.
2 - Personnel	- Besides technical capabilities based on information and communication technology (ICT), socio-emotional skills are demanded, such as tolerance for error, willingness to learn from mistakes, creativity, social and communication skills, collaborative work, team spirit, and information exchange.
3 – Company Organization	- Flattened and weak hierarchical structures, with flexible processes and decentralized arrangements that promote agile organization, faster decisions, and an entrepreneurial spirit; - Pilot projects are developed initially, and rollout strategies expand the experiences to the rest of the company; - Development of partnerships with research institutes and other companies, to foster Research, Development and Innovation activities; - Data exchange between company networks, through internet communities and cloud-based platforms, so that key issues can be discussed between companies.
4 - Preparing for the implementation of Industry 4.0 solutions	- External sources of information: best practices from other companies, as well as publications from academia, research institutes and company associations; - Internal sources of information: R&D,I activities and learning from failures. The best results occur when employees are involved in the process; they are responsible for applying new technology and operating the machines; - Form multidisciplinary teams. It is important to learn quickly from mistakes and to test new approaches flexibly in order to develop and deliver effective solutions.
5 - Integrating Industry 4.0 solutions	- Requires a retrofit of companies' infrastructure and systems; - Technologies related to connectivity with computers, sensors, microprocessors and actuators, to collect data from machines and perform their analysis.
6 - Financial feasibility	- Some companies implement Industry 4.0 through small, individually financed projects. Hard data on return on investment is obtained from pilot projects.

These lessons learned reveal that for the successful implementation of Industry 4.0, social issues (people, organization) are as important as technical issues. According to Avis (2018), there is a dialectical relationship between technology and

social relations. Technologies cannot be thought of as being outside the social relations in which the company is embedded.

2.4 Intellectual Capital Statement - InCaS

The Intellectual Capital Statement method most used today was developed by a European consortium called InCaS, as an acronym to the Intellectual Capital Statement method. The methodology was developed from the scientific coordination of the Fraunhofer IPK Institute, based in Berlin, Germany. In its preface, the guide explains that IC forms the basis for a company to offer high-quality products and services, as well as to realize organizational innovations.

The resulting method, called InCaS - Made in Europe (2014), is defined as a strategic management tool, designed to assess and develop an organization's IC. The method defines the main elements of InCaS, as well as their interrelationships, as illustrated in Figure 2.

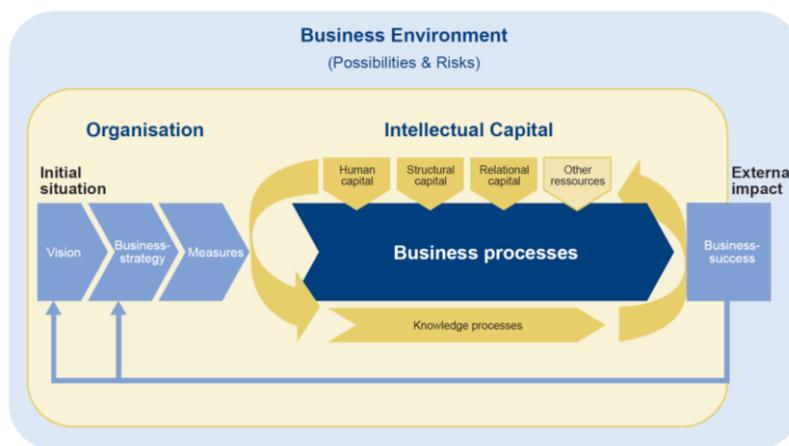


Figure 2. ICS structural model (INCAS, 2014).

They described, in this context, that IC is the study of the roots of a company's value, the measurement of the hidden dynamic factors that underlie the visible company of buildings and products. Those hidden factors typically take 3 forms, according to the collective research project "Intellectual Capital Statement – Made in Europe" (INCAS, 2014): Human Capital, Structural Capital and Relational Capital.

Human Capital (HC) is defined as "what the single employee brings into the value adding processes" (INCAS, 2014). The combined knowledge, skill, innovativeness and ability of the company's individual employees to meet the task at hand. It also includes the company's values, culture and philosophy. Human capital cannot be owned by the company (Edvinsson and Malone, 1998).

Structural Capital (SC) is defined as "what happens between people", "how people are connected within the company" and "what remains when the employee leaves the company" (INCAS, 2014). The hardware, software, databases, organizational structure, patents, trademarks and everything else of organizational capability that supports those employee's productivity. Unlike HC, SC can be owned and thereby traded (Edvinsson and Malone, 1998).

Relational Capital (RC) is defined as "the relations of the company to external stakeholders" (INCAS, 2014). Relationships to former, current and potential customers and suppliers; Relations with the public, including relations with former and potential employees and the general public; all relationships with internal and external investors, i.e. banks, owners, shareholders; and all relations to cooperation partners, such as R&D partnerships and networking activities (Mertins, Wang and Will, 2009).

3. METHODOLOGY

In order to achieve the goals of this research, a conceptual model is proposed and applied on a pilot project with a manufacturing company. The proposed model aims to support manufacturing companies in the development of action plans for the adoption of Industry 4.0 technologies, based on the concepts presented in Section 2. According to Kiel, Arnold, and Voigt (2017), when a research field has not yet reached full maturity, literature reviews can serve as basic rationales for a proposed framework.

3.1 InCaS 4.0 proposal

To compose this proposal, it was considered, as a starting point, that intangible assets are the basis for innovation, and that innovation feeds back on the ability to develop more agile and efficient processes. Therefore, for a manufacturing

company to be innovative, the central element of the framework proposal is the development of its Intellectual Capital Statement. Therefore, it was considered as a basis for this research the InCaS - made in Europe (INCAS, 2014) model.

However, to apply the InCaS in manufacturing companies, it was necessary to develop content adjustments, since the method was originally developed for application in service companies. In this sense, the content adjustments were made based on the conceptual review of Industry 4.0, more specifically, the identified socio-technical elements, as well as the main lessons learned related to Industry 4.0 adoption process. Both inputs were used in the revision of the IC factors, adjusting some factors and adding others, as presented in Table 2.

Table 2. Proposed IC Factors for IC assessment in manufacturing companies.

IC Dimensions	Index	IC Factors
Human Capital (HC)	HC1	Professional Competence
	HC2	Socio-emotional Competencies
	HC3	Employee Motivation
	HC4	Leadership Skills
Structural Capital (SC)	SC1	Cross-fertilization
	SC2	Governance & Decision Making
	SC3	Knowledge Management
	SC4	Innovation Experimentation
	SC5	Process Improvement and Optimization
	SC6	Corporate Culture
Relationship Capital (RC)	RC1	Relationship with Customers
	RC2	Relationships with Suppliers
	RC3	Relationships with development agencies
	RC4	Relationships with cooperation partners
Technological Capital (TC) – new dimension	TC1	Internet of Things [IoT]
	TC2	Cloud Computing & Cyber Security [Cloud]
	TC3	Big Data & Analytics
	TC4	Machine Learning [AI / Machine Learning]

3.2 IC Factors Assessment

After the proposal of IC Factors was developed, it was applied by means of a pilot project with a manufacturing SME, aiming to have, amongst its results, the IC Assessment, and an action plan proposal in order to nurture its own IC factors to prepare the company for Industry 4.0 base technologies adoption.

Once the list of IC factors has been defined, one must then perform the Quantity, Quality and Systematic Evaluation (QQS). The method proposes that a moderator should ask three questions for each defined factor, as described in Table 3.

Table 3. QQS Assessment, adapted from INCAS (2014).

QQS Dimension	Questions
(1) Quantity	Is the quantity / volume of this factor sufficient to achieve our strategic objectives? Do we have enough of this factor to achieve our strategic goals?
(2) Quality	Is the quality of this factor sufficient to achieve our strategic goals? Do we have the right factor, and is the quality of this factor good enough to achieve our strategic goals?
(3) Systematic Management	How systematically do we manage this factor to achieve our strategic goals? Do we have regular routines and measures in place to take care of and improve this factor?

When answering each question, each member of the multidisciplinary team should give their answer according to their own perception, using the scale indicated in Figure 3. In case of a divergence occurs during the voting, the moderator should provoke a debate among the participants, so that they can reach a point of convergence. At the end of each vote, the reasoning behind the result should be written down, as a memento of the analysis process. It is important that the top management vote last, to prevent their vote from biasing the results of the analysis.

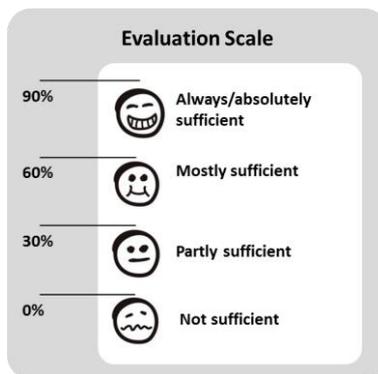


Figure 3. QQS Evaluation Scale, adapted from INCAS (2014).

An impact analysis of the importance of each IC factor in achieving the company's strategic objectives should also be performed. For this, each participant must vote using a simple scale: for each IC factor, the participant must choose a single value between 1 and N, where N is the number of IC factors used in the QQS Evaluation. The higher the value, the greater the degree of importance of this factor for the achievement of strategic objectives.

4. RESULTS AND DISCUSSION

This section presents the results of the application of the proposed method, InCaS 4.0. It starts by presenting the results of the application of the proposed InCaS 4.0 framework in a manufacturing SME, in a pilot project, followed by the prioritization of IC factors, and the consequent planning of an action plan for the adoption of Industry 4.0 technologies.

4.1 IC Factor Assessment (QQS Analysis)

The pilot project began with the selection of a company, which was a voluntary application among the participants of SENAI's "Rota 2030" priority program in partnership with the Ministry of Economy. Among the participants, the first to express its interest was company Alpha, a fictitious name assigned to the company selected for this research.

Company Alpha was founded in 1984, is headquartered in the city of São Bernardo do Campo, in the state of São Paulo, and provides manufacturing services to two industrial segments: the automotive industry, through lapping and grinding processes, and the oil and gas industry, through the production of parts for large-sized compressors. Its competitive differential has been the mastery of the lapping and grinding process, the in-house production of machine tools, and the investment in state-of-the-art machining centers for the production of compressor parts.

After conducting the IC Factors assessment meetings, the QQS analysis of company Alpha was obtained, as presented by Table 4

Table 4. Summary of the QQS evaluation of Company Alpha.

IC Dimensions	Quantity [% average]	Quality [average %]	Systematic Management [average %]	QQS assessment [% average]	Potential for Improvement [% average]
Human Capital (HC)	54%	51%	33%	46%	54%
Structural Capital (SC)	41%	41%	34%	39%	61%
Relationship Capital (RC)	39%	43%	33%	38%	62%
Technological Capital (TC)	17%	17%	18%	18%	83%
TOTAL [Average %]	38%	38%	30%	35%	65%

The results obtained, broken down into each dimension and each factor of IC, are illustrated by Figure 4.

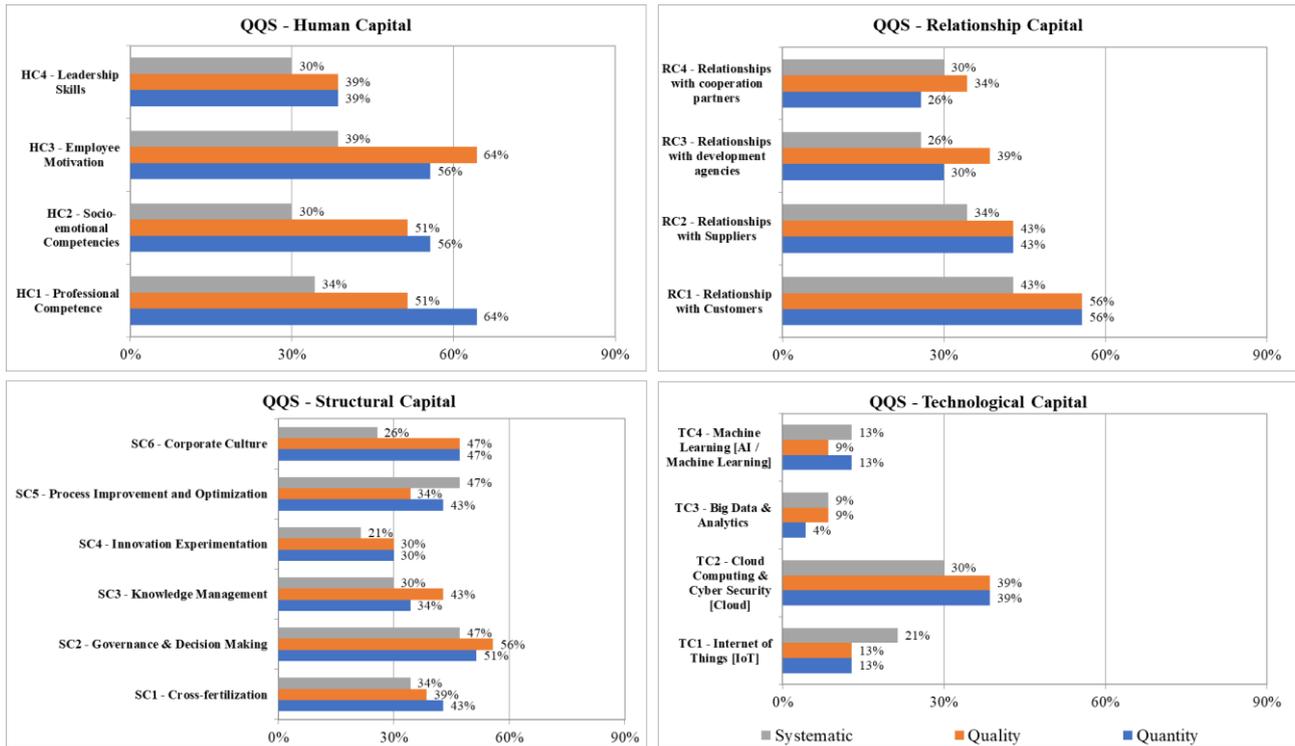


Figure 4. Results of the QQS Assessment of the human, structural, relational, and technological capital factors of company Alpha.

Also presented are the results of the analysis of the impact of IC factors on the achievement of the strategic objectives of company Alpha, illustrated in Figure 5.

Impact Analysis

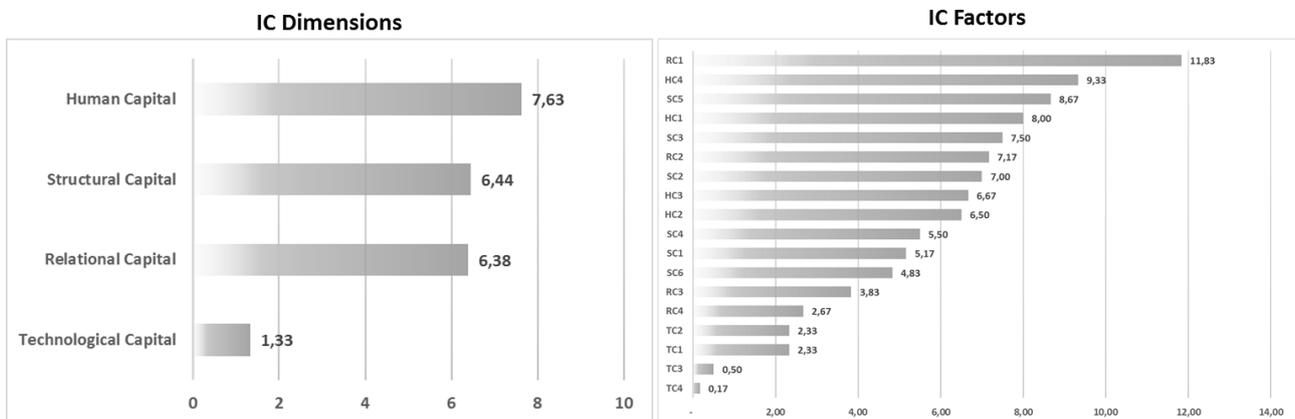


Figure 5. Results of the impact analysis, on the left, broken down by IC factors, and on the right, consolidated by IC dimension for company Alpha.

4.2 IC Factors Prioritization & Action Plan Development

The combination of the QQS Assessment with the impact analysis allowed for a portfolio management of IC factors, by means of the joint analysis of the average level of development of each IC factor (average of the QQS Assessment of each factor) and its relative importance for the fulfillment of the strategic objectives of company Alpha (impact analysis of each factor). These two pieces of information allowed a prioritization of IC factors to be targeted for the development of an action plan. Figure 6 illustrates Alpha's IC management analysis.

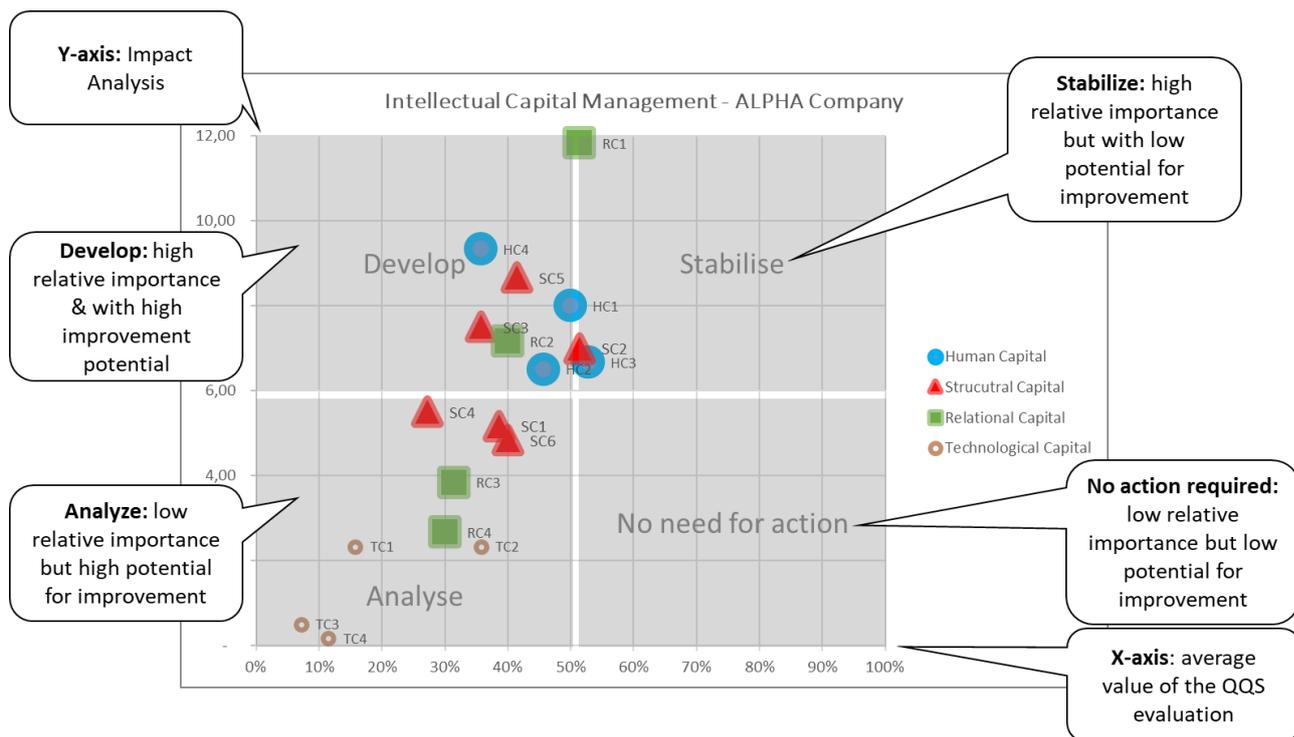


Figure 6. Prioritization of IC factors according to Alpha's IC analysis.

After a review by Alpha's multidisciplinary team, a list of prioritized IC factors was obtained, as shown in Table 5.

Table 5. Prioritization proposal for IC factors, developed by the multidisciplinary team of Alpha Company.

Action	Prioritization of IC Factors
Develop (Weaknesses)	HC4; SC5; RC4; SC4
Stabilize (Strengths)	RC1; SC2; HC1
Analyze	SC6; SC1; TC2; RC3; TC1; TC3; TC4
No action required	RC2; SC3; HC3; HC2

From the list of prioritized factors, Alpha's multidisciplinary team developed an action plan, as presented in Table 6.

Table 6. Action and indicator plan prepared by Alpha's multidisciplinary team.

Prioritized Factors	Planned Action	Description of Planned Action	Responsible	Due Date
CH4	(1) Define Alpha company's leader pattern	Define the leader's autonomy, how she/he manages the staff, what his limits are, his attitudes, etc.	Executive Director	March/2021
CH4	(2) Implement Alpha's leadership training program	Hold periodic meetings/workshops among leaders to discuss Alpha's company culture	Organization and Strategy Manager	December/2021
CE5	(3) Continuous improvement team implementation	Define an action plan for the improvement of all production processes	Compressor Unit and Automotive Unit Leaders	December/2021
CE5	(4) Optimization of key administrative processes	Use the BPM method to map and optimize key business processes	Materials Coordinator	December/2021
CH1	(5) Development of a training policy	Having a training policy that covers all the company's categories and that is your guide for investing in qualification	Human Resources Manager	December/2021
CR1	(6) Implement a marketing structure in the two business units	Enable B2B marketing	Compressor Unit and	December/2021

CE2	(7) Have action plans for each leader integrated into the Strategic Plan	Actions and decisions will be integrated to the strategy	Automotive Unit Leaders All leaders	December/ 2021
CE4	(8) Institutionalize the Compressor Unit's Innovation Committee	Institutionalize the initiative to capture, debate and implement product, process and material innovation	Compressors Unit Leader	December/ 2021
CR4	(9) Identify and prioritize relevant projects to be developed with the partner network	Having a list of selected projects	Industry Innovation Leader	December/ 2021

4.3 Discussion

Regarding the prioritization of IC factors, a higher perceived impact, by company Alpha, of Human Capital factors (7.63) was observed. In second place is positioned Structural Capital (6.44) practically tied with Relational Capital (6.38). In last place of impact perception, Technological Capital was observed (1.33).

It was also observed that the prioritization suggested by the QQS Analysis allowed company Alpha to develop an action plan, which aims to nurture its IC, preparing it for the adoption of Industry 4.0 technologies.

When analyzing the developed action plan against the state-of-the-art review, it was verified that actions 1, 2 and 5 (Table 6), related to Human Capital factors, are aligned with the good practices identified by Veile *et al.* (2019) in companies successful in adopting Industry 4.0 technologies.

Regarding the Structural Capital factors, it was observed that actions 3, 4, and 7 (Table 6) are aligned with Asif's (2017) proposals. Actions 3 and 4, referring to the improvement of key manufacturing and administrative processes, respectively, and action 7, referring to the integration of strategic planning of leaders, are considered key mechanisms by companies that have adopted Industry 4.0 (Veile *et al.*, 2019). Also noteworthy is action 8, related to Innovation Experiments (CE4), which is a way to start developing knowledge about the adoption of Industry 4.0 technologies. This action is in line with the good practices identified by Veile *et al.* (2019).

Finally, regarding the Relational Capital factors, it was observed that the company prioritized CR1 to further enhance it, resulting in a plan with an action to implement a relationship structure (marketing) in the two Business Units (Action 6). Regarding action 9, it was observed that it is in line with the good practice, identified by Veile *et al.* (2019), in the adoption of Industry 4.0 technologies.

5. CONCLUSION

The work structure proposed in this article, the InCaS 4.0 framework, incorporated elements of lessons learned from companies that have already adopted Industry 4.0 technologies, through the review of IC factors. This method, which aims to support manufacturing companies to prepare themselves to adopt Industry 4.0 technologies, was validated through a pilot project developed in a manufacturing company. In this pilot project, the IC Analysis was performed through the QQS evaluation, and through the Impact Analysis of the IC factors. By combining these two assessments, it was possible to support the company in prioritizing its IC factors. This prioritization served as input for the company to develop an action plan. The planned actions were adherent to the lessons learned observed in the literature, validating the proposed method, thus supporting the company to prepare for the adoption of Industry 4.0 technologies by nurturing its Intellectual Capital.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

- Ahmed, S. S. *et al.*, 2019. "Intellectual capital and business performance: the role of dimensions of absorptive capacity". *Journal of Intellectual Capital*, v. 21 n. 1, p. 23-39.
- Avis, J., 2018. "Socio-technical imaginary of the fourth industrial revolution and its implications for vocational education and training: a literature review". *Journal of Vocational Education & Training*, v. 70, n. 3, p. 337-363.
- Brasil, 2015. "Annual Social Information Report – RAIS". *Ministry of Economy*, Brasília.
- Edvinsson, L. and Malone, M., 1997. "Intellectual capital: Realizing your company's true value by finding its hidden brainpower". Harper Collins, New York.

- Frank, A.G., Dalenogare, L.S. and Ayala, N.F., 2019. "Industry 4.0 technologies: Implementation patterns in manufacturing companies". *International Journal of Production Economics*, v. 210, p. 15-26.
- Garcia, J. and Alvarado, A., 2013. "Problems in the implementation process of advanced manufacturing technologies". *International Journal of Advanced Manufacturing Technology*, v. 64, n. 1-4, p. 123-131.
- Ghobakhloo, M., 2018. "The future of manufacturing industry: a strategic roadmap toward Industry 4.0". *Journal of Manufacturing Technology Management*, v. 29, n. 6, p. 910-936.
- Horváth, D.; Szabó, R.Z., 2019. "Driving forces and barriers of Industry 4.0: Do multinational and small and medium-sized companies have equal opportunities?" *Technological Forecasting & Social Change*, v. 146, p. 119-132.
- INCAS, 2014. "InCaS: Intellectual Capital Statement – Made in Europe". Brussels: European Commission, http://wissenskapital.info/wp-content/uploads/2014/10/european_ics_guideline.pdf. Accessed 14 March 2021.
- Kagermann, H. et al., 2013. "Recommendations for implementing the strategic initiative Industrie 4.0: final report of the Industrie 4.0 working group", ACATECH, Frankfurt am Main, Germany, <https://en.acatech.de/publication/recommendations-for-implementing-the-strategic-initiative-industrie-4-0-final-report-of-the-industrie-4-0-working-group/>. Accessed 8 February 2021.
- Kiel, D.; Arnold, C.; Voigt, K.I., 2017. "The influence of the industrial Internet of Things on business models of established manufacturing companies – A business level perspective" *Technovation*, n. 68, p. 4-19.
- Mahmood, T. and Mubarik, M.S., 2020. "Balancing innovation and exploitation in the fourth industrial revolution: Role of intellectual capital and technology absorptive capacity". *Technological Forecasting and Social Change*, v. 160.
- Meindl, B, Ayala, N.F.; Mendonça, J. and Frank, A.F., 2021. "The four smarts of Industry 4.0: Evolution of ten years of research and future perspectives". *Technological Forecasting and Social Change*, v. 168.
- Mertins, K.; Wang, W.H.; Will, M., 2009. "InCaS: Intellectual Capital Management in European SMEs – its strategic relevance and the importance of its certification". Fraunhofer IPK, vol. 7.
- Morrar, R., Arman, H. and Mousa, S., 2017. "The fourth industrial revolution (Industry 4.0): A social innovation perspective". *Technology Innovation Management Review*, v. 7, n. 11, p. 12-20.
- Mubarik, M.S., 2015. "Human capital and performance of small & medium manufacturing enterprises: a study of Pakistan". PhD Thesis in Economics and Administration, University of Malaya, Kuala Lumpur, Malasia.
- Schwab, K., 2016. *The Fourth Industrial Revolution (in Portuguese)*. Editora Edipro, São Paulo.
- Schuh, G. et al., 2017. "Industrie 4.0 maturity index: Managing the digital transformation of companies". Munique, Germany, <https://en.acatech.de/publication/industrie-4-0-maturity-index-managing-the-digital-transformation-of-companies/>. Accessed 8 February 2021.
- Sony, M. and Naik, S., 2020. "Industry 4.0 integration with socio-technical systems theory: A systematic review and proposed theoretical model". *Technology in Society*, v. 61.
- Veile, J. et al., 2019. "Lessons learned from Industry 4.0 implementation in the German manufacturing industry". *Journal of Manufacturing Technology Management*, v. 31, n. 5, p. 977-997.

8. RESPONSIBILITY NOTICE

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