S&G Journal

S&G JOURNAL
ISSN: 1980-5160

PÓS-GRADUAÇÃO DINÂMICA DOS OCEANOS E DA TERRA UFF

THE INFLUENCE OF INTELLECTUAL CAPITAL ON VALUE CREATION IN THE LIFE CYCLE: A BIBLIOMETRIC STUDY

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ABSTRACT

The main findings were identifying the eight guidelines comprising intellectual capital in its 21 items, establishing their relationship with the life cycle but not identifying their impact level. Bibliometry was performed to study the intellectual capital theme as value generation in lifecycle management from the literature, using an exploratory and bibliographic methodology. In the last three decades, the subject was discussed with greater adherence in the segment of economic sciences, which drove greater amplitude due to socio-environmental issues present in the construction of the knowledge valuation. The research allowed the understanding of the transformation of the matters referring to intellectual capital and the management form of the products' life cycle in the organizations and the identification in the literature of the eight guidelines and the 21 items comprising intellectual capital. This study used the Scopus database as a search engine between 1986 and 2017, treated qualitatively by the VOSviewer software. It was not possible to identify the impact degree of the intellectual capital guidelines on the product life cycle in the present study; however, there is a direct relationship between intellectual capital, the cycle, and a proposal for an intelligent lifecycle management model based on the intellectual capital guidelines.

Keywords: Human Capital; Intellectual Capital, Lifecycle Management; Bibliometrics.

PROPPI / DOT
DOI: 10.20985/1980-5160.2022.v17n1.1771

S&G Journal
Volume 17, Number 1, 2022, pp. 31-44
DOI: 10.20985/1980-5160.2022.v17n1.1771

INTRODUCTION

To be competitive, companies need to improve their controls constantly. Qualitatively managing their capital is essential for the continuity and maintenance of their operations.

In the 2018 and 2019 biennia, companies in the construction industry suffered a 2% reduction, a fact noted from 2015, with an 18.7% drop in their revenues. The retraction of the national economy represented the largest drop recorded in history, beginning in 1996. This reduction has become a worrisome factor, and with the crisis triggered by the coronavirus pandemic, COVID-19, this has become even more evident.

Then, it has become crucial to understand the direct impact on the operational and financial results arising from the available tangible and intangible resources and also their production chain for the survival of the business (Makrominas, 2016; McGrattan, 2017; Vedachedu, 2017; Junior and Oliveira, 2017; Popov and Vlasov, 2018; Xu and Liu, 2019).

A direct and univocal relationship between capital (human, intellectual, organizational, and customer) regarding new product development, its valuation, and acceptance has been identified in the literature (Malavski, 2010; Foerster, 2011; Martins, 2012; Derun, 2013; Makrominas, 2016; McGrattan, 2017; Vedachedu, 2017; Junior and Oliveira, 2017; Popov and Vlasov, 2018; Xu and Liu, 2019).

Evolutionary economics, or resource-based theory, achieved through business strategy and represented by assets (distinct resources centered on the market, man in intellectual property, and infrastructure), focuses on organizational knowledge and competency development, emphasizing mobilization, productivity, and creativity (Mouritsen, 1998; Chen et al., 2014; Vedachedu, 2017).

Chen et al. (2014) demonstrated empirical evidence through hypotheses supporting this prediction and indicating that intellectual and organizational capital can favor and influence product performance, particularly through improved customer capital management.

For Chen (2014), products are vital for companies' profit generation and are managed and developed by human intellectual capital. They improve market share by pointing to a competitive advantage, consequently influencing the profitability of companies in a direct way.

The metaphor that presents the visible parts of the tree (trunk, branches, and leaves), which reflect the representative and illustrative forms of a company and how the market sees it, is translated by its tangible and intangible assets and resources. Its fruits represent profit, products, and services, while its roots symbolize the invisible part, meaning the intangible assets (Mouritsen, 1998; Malone, 1998; Derun, 2013; Bento, 2016).

One of these roots that deserve to be highlighted is intellectual capital. For the tree to thrive and produce good fruit, have fine foliage, and provide shade, it must be nurtured with strong and healthy roots and properly fertilized soil (Mouritsen; 1998; Malone, 1998; Derun, 2013; Bento; 2016).

It is inferred that the leaves are the operational, strategic, and tactical processes that reflect and protect the alignment of the corporate culture and governance of the entity. The shade produced reflects its image and reputation, intended to attract investments and stakeholders to the business. Finally, the soil is where it was established and inserted, i.e., the market in which it operates. It is up to its managers to interpret which nutrients the "tree" needs and then manage it efficiently and effectively for the corrective and preventive maintenance of the business.

As of 2004, research establishing the interdependence between intellectual capital and the life cycle with parametric and non-parametric analysis through modeling has intensified.

A concentration of papers that established a relationship between intangibles and product lifecycle management was observed. The treatment of tangible and intangible values focuses on product composition and has different ways of evaluation, which makes its measurement complex and difficult to understand (Diao *et al.*, 2016). This has contributed to its evolution, which inversely carries the investment's cost/benefit ratio and maturity term over time (Diao *et al.*, 2016).

Product lifecycle management is established as a strategic business management methodology applied to innovation, covering the conception to the disposal and retrofit of the product. It also represents the rational and concatenated management of the consecutive phases of conception, procurement of inputs, and final disposal (Dzikuć, 2015).

For properly measuring the life cycle of the products applied, the construction industry, under the prism of the eight fundamental aspects of eco-efficiency, uses quantitative methods for its evaluation (Santos *et al.*, 2016). **Figure** 1 demonstrates these possibilities:

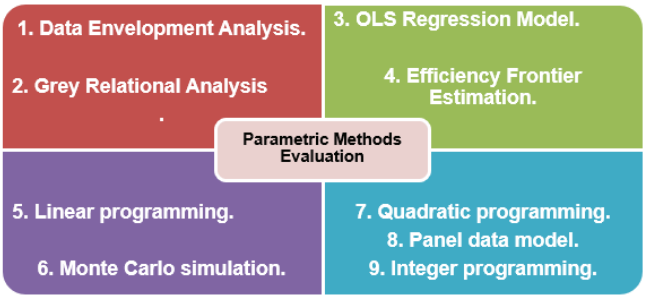

Figure 1. Methodology of eco-efficiency evaluation
Source: Adapted from Santos *et al*. (2016)

This analysis enabled the proposal of this article, which intends to verify the scientific evolution of the research developed on the influence of intellectual capital and its guidelines, as well as an existing methodology at the product lifecycle management level.

Given this, the problem of this research aims to verify the existence of a scientific gap by mapping and developing the following central theme: "**Identification of the guidelines that make up intellectual capital and its relationship with the life cycle of the products**," considering the period from 1986 to 2017 as the delimiting factor. A bibliometric analysis was used as a methodological procedure.

Text and citation analysis for Santos et al. (2016) enables systematic, rational, evaluative, and comprehensive insight in an efficient, effective, and safe manner into how science approaches a particular analyzed subject.

This form is qualitative, quantitative, managerial, and widely disseminated and accepted by academia for providing new possibilities and thematic arrangements, ultimately configuring knowledge advancement and evolution and translated by the bibliometric study (Santos et al., 2016).

As for the qualitative-quantitative aspect, from the main objective and the key concepts (thematic areas to be studied), a transversal framework of embryonic keywords was built, providing a progressive adjustment to explore the research findings.

Articles indexed by Scopus[1], were analyzed, generated by filters prepared through Boolean architecture, and evaluated using the software VOSviewer[2].

This research analyzed different characteristics of the related publications on the studied thematic areas, namely: (1) Lifecycle thinking; (2) Product Lifecycle management; (3) Life cycle in the construction industry; (4) Concepts of intellectual capital in the literature; (5) Theoretical evolution of intellectual capital; and (6) Intangibles and lifecycle management.

Through the VOSviewer software, this application allowed analyzing the bibliometric data and generating the clusters. They were obtained by the files generated in the search engines of the database used (Scopus).

As for the structure of this research, it was conducted in four parts: (1) introduction, (2) methodology, (3) results, and (4) conclusion.

METHODOLOGY

Bibliometric method

The successful choice of the methodology to be used needs to fit the question and the problem on which the entire research theme is focused, enabling the results to explore and perform the analyses they propose (Raffaghelli, Cucchiara, and Persico, 2015; Smith, 2015).

In this context, the aim of this research is characterized as bibliometric, enabling the investigation and cooperation to understand how the information produced sheds light on the clarification of confirmed events and phenomena. The results found work as a basis for the proposed scientific analysis (Zuccala, 2004; Kostoff, 2005).

The bibliometric methodology presents knowledge about three constitutive prisms through the quantitative determination of bibliographic data (Santos et al., 2016). See below for an understanding of these prisms:

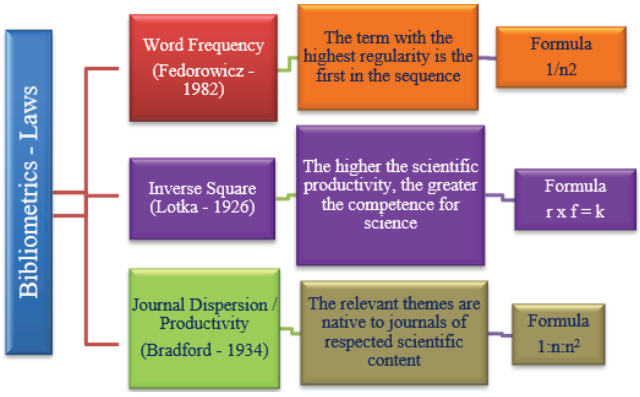

Figure 2. Methodology of eco-efficiency evaluation
Source: Adapted from Santos *et al*. (2016)

Bibliometry is a guiding landmark in the literature review, contributing to scientific advancement in any area of knowledge and establishing itself for excellence and notoriety. Boolean analysis of the data also allows measuring the relevance factor of scientific productions in the proposed the-

S&G Journal
Volume 17, Number 1, 2022, pp. 31-44
DOI: 10.20985/1980-5160.2022.v17n1.1771

matic areas, providing the validation of keywords that will guide scientific research rationally and effectively.

Research gap through the bibliometry performed

The context and gap were made possible by the research of the thematic areas studied, initially focusing on a qualitative data study. Such analysis directed the formulation of the research question and understanding of the causal analogies made, supported by the proposed context, which in its conception has a dual purpose: to justify and explain its relevance (Treinta et al., 2014).

Initially, the "AND" and "OR" operators, combined with the "ALL" structurer, were considered, presenting the documents in which the searched word was found in one of the possible analysis variables: article title, source title, language, author, publisher, affiliation, abstract, keywords, references, DOI, ISBN, ISSN, CODEN, subjects, volume fields, publication year, sequence bank, sequence bank number, number, chemical name, CAS registry number, manufacturer, publisher, or conferences.

The "AND" and "OR" operators were kept in the two subsequent rounds, combined with the more particular search structurers.

The application of bibliometry set up the strategy of this article, which substantiated the research gap by generating two Boolean logics from the composition of the keywords of the research thematic areas, intending to verify the assertiveness of the concentration of documents using the "AND" and "OR" logic. Then, the returned documents were read after searching for the guiding keywords.

After validation of the Boolean, the universe of documents used was determined. They contributed significantly and relevantly to the observation of the existing gap, which is established in the following premise: the absence of scientific research presenting the research problem "**How do intangible intellectual capital and its guidelines qualitatively and quantitatively favor lifecycle management?**" within the scientific literature, considering the period from 1986 to 2017.

The validating method used was a bibliometric study, based on documents obtained from scientific publications, indexed using the Scopus database.

Mapping of research indexed in Scopus database

The validation of the research gap was driven by the drivers using Boolean architecture, built by the guiding keywords, aligned to the objective of this work. It was possible to identify a universe of 687 national and international documents, all of which were taken from the Scopus database and indexed journals.

A bibliometry was carried out to formulate the Boolean first by separating the thematic areas that guided the search for the research gap: ***(1) Lifecycle thinking; (2) Product lifecycle management; (3) Life cycle in the construction industry; (4) Concepts of intellectual capital in the literature; (5) Theoretical evolution of intellectual capital; and (6) Intangibles and lifecycle management***. Next, an analysis was performed by reviewing the existing literature and bibliometry on these subject areas.

The logical structure was elaborated from the research strategy by searching the CAPES website in the CAFe environment, where bibliographic content is made available through the periodicals portal through password access available in the master's and doctoral programs of the participating institutions, enabling this research to be carried out[3].

The Boolean operators and cognitive structures were constructed for the gap validation, and the architecture of the Boolean operators was employed in the construction of the art, with 687 as the total number of documents available after the refinements[4]. The final formed Boolean was: (ALL ("life" AND "cycle" AND "thinking") OR ALL ("life" AND "cycle" AND "management") OR ALL ("life" AND "cycle" AND in AND "construction") OR ALL ("intangible" AND "assets") AND ALL ("intellectual" AND "capital")) AND DOCTYPE ("ar" OR "re") AND PUBYEAR > 1989 AND (EXCLUDE(SUBJAREA, "SOCI") OR EXCLUDE (SUBJAREA, "ECON") OR EXCLUDE (SUBJAREA, "DECI") OR EXCLUDE (SUBJAREA, "COMP") OR EXCLUDE (SUBJAREA, "ENVI") OR EXCLUDE (SUBJAREA, "ARTS") OR EXCLUDE (SUBJAREA, "PSYC") OR EXCLUDE (SUBJAREA, "ENER") OR EXCLUDE (SUBJAREA, "MATH") OR EXCLUDE (SUBJAREA, "MEDI") OR EXCLUDE (SUBJAREA, "AGRI") OR EXCLUDE (SUBJAREA, "BIOC") OR EXCLUDE (SUBJAREA, "MULT") OR EXCLUDE (SUBJAREA, "EART") OR EXCLUDE (SUBJAREA, "MATE") OR EXCLUDE (SUBJAREA, "CENG") OR EXCLUDE (SUBJAREA, "NURS") OR EXCLUDE (SUBJAREA, "HEAL") OR EXCLUDE (SUBJAREA, "PHAR") OR EXCLUDE (SUBJAREA, "PHYS") OR EXCLUDE (SUBJAREA, "NEUR") OR EXCLUDE (SUBJAREA, "CHEM") OR EXCLUDE (SUBJAREA, "IMMU") OR EXCLUDE (SUBJAREA, "VETE") OR EXCLUDE (SUBJAREA, "Undefined")).

Data treatment and analysis

From the data obtained in the Boolean construction, the analysis of the findings for the gap foundation was carried out. From this qualitative data analysis and result presen-

tation, the following evolutionary order was established for treatment:

Item	Analysis studied	Gapping period
01	The quantitative evolution of indexed research	1986 to 2017
02	The evolution of indexed studies in the five journals that have published the most	
03	Ten authors who have published the most	
04	Ten countries that have published the most	
05	Five most adherent areas of scientific knowledge	

Chart 1. Qualitative data analysis and results presentation - Scopus
Source: Prepared by the authors (2021)

Data from qualitative analyses were obtained using Microsoft Excel software, which allowed for calculation and the creation of graphs and tables. As for the data analysis and cluster formation, the following premise was followed:

Item	Clusters	Bibliometric System
01	Co-authorship	VOSviewer1
02	Cooccurrences	
03	Citations	

Chart 2. Qualitative data analysis and results presentation - Scopus
Source: Prepared by the authors (2021)

According to the study's central objective, 687 documents in CSV (excel) format were exported from the SCOPUS database to the VOSviewer analysis database, where the fields and data types presented in the following table were considered:

Table 1. Data and fields from the Scopus database considered for migration in the VOSviewer software.

Data extracted from databases	Fields considered for the analyses
Citation information	Author(s), document title, year, EID, source title, volume, issue, pages, citation count, source document Type, and DOI
Bibliographical information	Affiliations,
Abstract and Keyword	Abstract, author keywords, index keywords
References	References.

Source: Prepared by the authors (2021)

After export, the application was parameterized to use the "full" counting method for the three types of analysis performed to generate cluster maps based on bibliographic data.

The following tables present the consolidated description of the counting method and the analysis types used in this phase of the research:

Table 2. Counting methods used in the VOSviewer software

Counting method	
Type	Understanding its functionality
Full	Considers for counting purposes the occurrence or non-occurrence of a term associated with a document.
Fragmented	The relevance of a link between terms is detailed as follows: each reference, citation, or document equally matches the total number of terms analyzed.

Source: Van Eck and Waltman (2010)

Table 3. Types of analysis used in the VOSviewer software

Analysis Typology	
Type	Descrição e entendimento
Co-authorship	The relationship between the items is established through the number of documents with co-authorship.
Cooccurrence	The relationship between the items is established through the number of document occurrences.
Citation	The relationship between the items is established through the number of times the authors of the documents are cited.

Source: Van Eck and Waltman (2010)

The results allowed establishing the combinations below:

Table 4. Possibility tree

Item	Description
1	Lifecycle thinking
2	Product lifecycle management
3	Life cycle in the construction industry
4	Intellectual capital concepts in the literature
5	Theoretical evolution of intellectual capital
6	Intangibles and lifecycle management

Source: Prepared by the authors (2021)

1 Free software, available at: www.vosviewer.com. Accessed on: 10/04/2021

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DOI: 10.20985/1980-5160.2022.v17n1.1771

After the data were processed using Microsoft Excel and VOSviewer software, the analysis phase of the results began.

RESULTS AND DISCUSSION

Quantitative evolution of topics until 2016 and performance of the main journals

The elaboration and survey of the list of selected keywords that guided and grounded the research gap were: (1) Lifecycle thinking; (2) Product Lifecycle Management; (3) Life cycle in the construction industry; (4) Concepts of intellectual capital in the literature; (5) Theoretical evolution of intellectual capital; and (6) Intangibles and lifecycle management.

The main thematic areas found in this analysis were Business, Management and Accounting, Social Sciences, Engineering, Economics, Econometrics, and Finance. As for the type, a higher document concentration in article format was detected, totaling 72.62% of the findings, with 15.12% of publications in events and 4.7% of documents as literature reviews.

Concerning scientific production, there has been a considerable increase in the study areas related to intellectual capital and the life cycle applied to the construction industry, with its highest peak in 2015, with 73 publications on the subject.

The journals with the highest incidence were the following: Intellectual Capital, Intangible Capital, Procedia CIRP, International Journal of Hospitality Management, and International Journal of Production Research.

Another factor to be highlighted was the increase in citations per year, totaling 7,002 citations in 2017. The main subject areas were Engineering, Accounting and Finance, and Economics.

With clustering in the word cloud formation, the higher incidence was found in the following words: Life Cycle, Competition, Knowledge Management, Intangible Assets, and Intellectual Capital.

The tables below present the understandings and the analysis of the content extracted using Microsoft Excel and VOSviewer software through the Scopus database.

Among the authors observed in the constellations formed in the VOZviewer, the following was pointed out: Joia (2009), Windsperger (2009), Peruzzini (2016), Mathur (2014), and Jugdev (2014). The predominant languages for elaborating the scientific finding were English and Spanish. As for the studied areas' keywords, they focused on "Intellectual Capital," "Life Cycle," and "Intangible Asset."

Keyword co-occurrence network

Relationships were made based on the number of times the documents and journals (and other fields used for the analyses) were related to the themes: intangible, intellectual capital, multivariate analysis, and life cycle.

After processing the data obtained from the document consolidation and their fields, it was possible to establish a synthesis for understanding the publications, the number of citations, and the relevance factor of the terms, along with the countries of concentration, the organizations responsible, and the journals with the highest incidence on the theme related to the guiding keywords. Below are the tables related to this understanding:

Total citations			
Autor	Total	Countries	Total
Jugdev L.	107	The United States	4651
Mathur G.	107	The United Kingdom	1565
Baxter R.	66	Australia	928
Windsperger J.	57	Spain	745
Joia L.A.	44	Taiwan	670
Peruzzini M.	28	Canada	593

Chart 5. Quantitative citations by author, country, and responsible organization
Source: Prepared by the authors (2021)

Guiding Keywords	Number of events
intangible assets	45
intellectual capital	41
innovation	19
service quality	19
customer satisfaction	18
knowledge management	17
human capital	12
corporate reputation	11
life cycle	76
intangible assets	55
intellectual capital	43

Chart 6. Guiding keywords versus number of occurrences
Source: Prepared by the authors (2021)

The term "intellectual capital" is not something new in society; however, its form of treatment has changed over

Item	Understanding Relationship x Publications	Analyses performed
01	Thematic Area	The main thematic areas found were Business, Management and Accounting, Social Sciences, Engineering, Economics, Econometrics, and Finance.
02	Type	The highest document concentrations were found in scientific article format with 75.62%; for publications in international conferences, it was 15.12% and 4.7% for literature reviews.
03	Scientific production per year	This analysis showed a considerable increase in the topics studied in the subject areas, intangible, life cycle, and multivariate analysis from 2003, reaching 73 publications in 2015.
04	Quantity per journal	It was observed that the periodicals Journal of Intellectual Capital, Intangible Capital, Procedia CIRP, International Journal of Hospitality Management, and International Journal of Production Research showed the highest concentration of publications on the keywords used.
05	Thematic area / number of publications	The main subject areas where publications were concentrated were Business and Finance, Management and Accounting, Social Sciences, Engineering, Economics, and Econometrics.
06	Impact Factor SJR, SNIP/thematic area	In this graph, one of the four thematic areas with the highest concentration was presented, showing an increase from 2010, reaching double the impact factor, with the Citation Score reaching 0.56, SJR reaching 0.22, and SNIP reaching 0.065.
07	Citation number per year	An increase in the number of citations was observed starting in 2016, going up from 126.
08	Subject area / number of publications	The quantity observed was approximately 53 from 2016. The highest quantity previously found was in 2013, with 51 documents.
09	Impact Factor SJR, SNIP / thematic area	This graph presented one of the four thematic areas with the highest concentration, showing an increase from 1999. In 2016, the Citation Score showed 3.52, with SJR at 1.956 and SNIP at 1.862.
10	Quantitative citation per year	An increase in the number of citations was observed from 2017, with approximately 7,002 citations. The highest percentage previously detected was in 2016, with 6,402 citations.

Chart 3. Explanation of the graphs, understanding, and analysis synthesis of the results

Source: Prepared by the authors (2021)

time. This is due primarily to the lack of understanding and to its discoveries; nevertheless, its intensification as an asset, i.e., possessing value for the company, took place in the 1990s.

The concept of intellectual capital translates the sum of the following capitals: (1) Structural, (2) Human, and (3) Relational. It represents the greatest asset and equity available to entities and is also characterized by the sum of skills, experiences, and competencies developed over time. Its source and origin are knowledge (Malavski, 2010; Foerster, 2011; Martins, 2012; Derun, 2013; Makrominas, 2016; McGrattan, 2017; Vedachedu, 2017; Junior and Oliveira, 2017; Popov and Vlasov, 2018; Xu and Liu, 2019).

In the literature, there is a strong indication and scientific evidence of the relationship between intellectual capital and value creation for the company (Malavski, 2010; Foerster, 2011; Martins, 2012; Derun, 2013; Makrominas, 2016; McGrattan, 2017; Vedachedu, 2017; Junior and Oliveira, 2017; Popov and Vlasov, 2018; Xu and Liu, 2019). It was possible to identify the measurement models built to evaluate intellectual capital over time with the literature studied[6]. From the bibliometric study, the main findings in the literature were identified, which guaranteed to point out and identify eight guidelines that influence and impact intellectual capital and its valuation over time, subdivided into 21 items (Malavski, 2010; Foerster, 2011; Martins, 2012; Derun, 2013; Makrominas, 2016; McGrattan, 2017; Vedachedu, 2017; Junior and Oliveira, 2017; Popov and Vlasov, 2018; Xu and Liu, 2019).

Below are the methodologies for applying intellectual capital and the relationship of the eight guidelines and their 21 items that influence it:

(1) Human capital resources and their development, characterized by complete knowledge and its dissemination (Derun, 2013; Martins, 2012; McGrattan, 2017; Lin, Yu, Wu, and Cheng, 2017; Duodu and Rowlinson, 2020), skills, and employee creativity, containing the items: human resources, skills, competencies (Malavski; Lima; Costa, 2010), and development.

(2) Structural capital, represented as organizational capi-

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Item	Understanding Relationship x Publications	Analysis
11	Thematic area / number of publications	The quantity observed was approximately 174 as of 2014. The highest quantity previously found was in 2012, with 152 documents.
12	Impact Factor SJR, SNIP / thematic area	In this graph, one of the four thematic areas with the highest concentration was presented, showing an increase as of 1999. In 2016, the Citation Score was 2.67, SJR was 1.463, and SNIP was 1.416.
13	Citation number per year	An increase in the number of citations was observed from 2016 and 2017, with 16,406 citations, approximately.
14	Thematic area / number of publications	The quantity observed was approximately 682 as of 2017. The highest quantity previously found was in 2012, with 484 documents, and 2013, with 475 documents.
15	Impact Factor SJR, SNIP / thematic area	In this graph, one of the four thematic areas with the highest concentration was presented, showing an increase as of 1999. In 2016, the Citation Score was 3.05, with SJR at 0.72 and SNIP at 2.283.
16	Number of citations per year	An increase in the citation number was observed from 2015, with 2,516 citations. In 2017, we obtained 2,507.
17	Subject area / number of publications	The quantity observed was approximately 44 from 2006 and 2007. In 2017, it showed the same number of 44 documents.
18	Impact Factor SJR, SNIP / thematic area	This chart presented one of the four subject areas with the highest concentration, showing an increase as of 2013, with a SNIP of 1,297.
19	Quantitative of citation per year	An increase in the citation number was observed from 2016, with 5,059 citations. In 2017, 6,846 were obtained.
20	Subject area / number of publications	The quantity observed was approximately 1,742 as of 2016. In 2017, it showed the same quantity of 818 documents.
21	Keywords clustered using VOSviewer software	The keywords that obtained the highest concentration and formed clouds for cluster formation were Life Cycle, Competition and Knowledge Management, Intangible Assets, and Intellectual Capital.

Chart 4. Explanation of the graphs, understanding, and synthesis of the analysis results

Source: Prepared by the authors (2021)

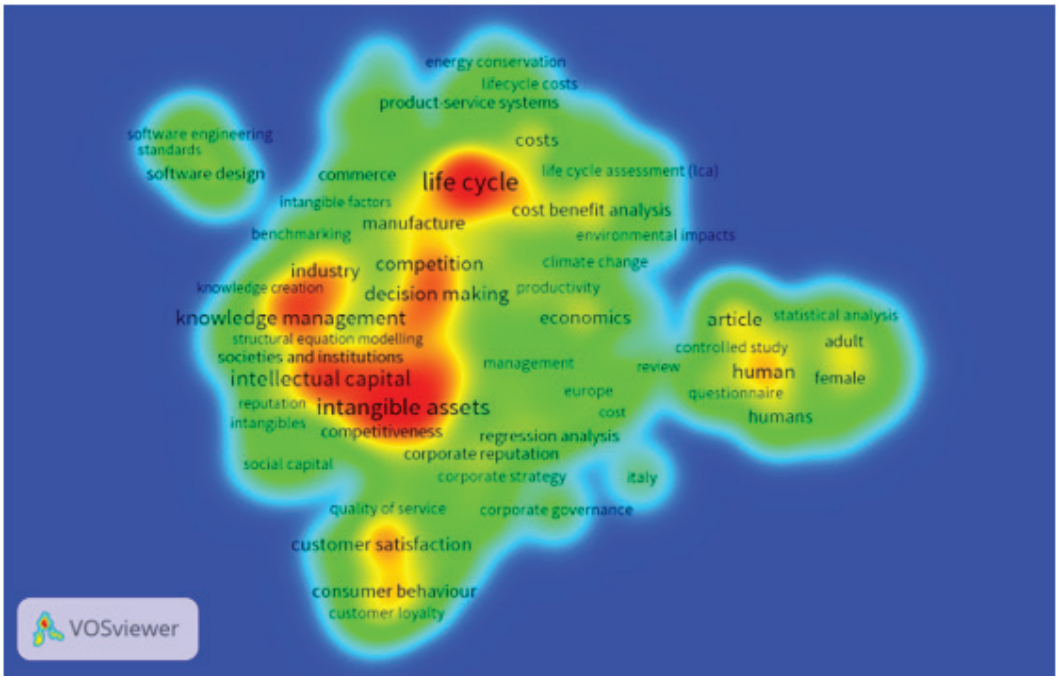

Figure 4. Construction of the research gap; Author / keywords by sensitivity; Boolean VOSviewer

Source: Elaborated by the authors (2021)

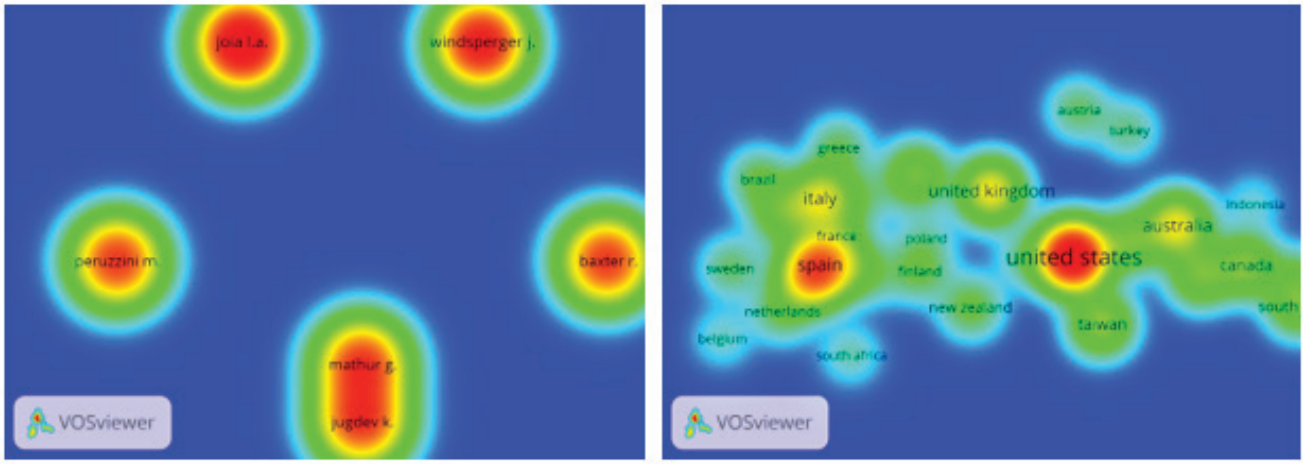

Figure 5. Network of co-authorship between countries - Scopus database
Source: Prepared by the authors (2021)

tal and intellectual property (Stewart, 1994; Xu; Liu, 2019), with the items: knowledge (Malavski; Lima; Costa, 2010; Ritvanen; Sveiby, 2017; Lin, Yu, Wu, and Cheng, 2017; Duodu and Rowlinson, 2020) and experience.

(3) Secondary intellectual capital and corporate culture (Mouritisen, 1998; Nascimento; Souza Junior, 2019) composed of organizational structure and corporate culture.

(4) Intellectual and relational property assets represented by trademarks and symbols (Derun, 2013; Edvinsson; Malone, 1998), copyrights, and customer and stakeholder assets, with the items: intangible assets (Mouritisen, 1998; Nascimento; Souza Junior, 2019) and customer assets.

(5) Company infrastructure assets, consisting of technology training and capacity building, company databases (Popov; Vlasov, 2018; Ritvanen; Sveiby, 2017), and operating methods. Items: trademarks (Stewart, 1994; Xu; Liu, 2019; Derun, 2013; Edvinsson; Malone, 1998), symbols, and copyrights.

(6) Market assets, established by intangible assets related to transactions that determine the firm's positioning in the market (Mouritisen, 1998; Nascimento; Souza Junior, 2019), containing company databases (Malavski; Lima; Costa, 2010; Martins, 2012; McGrattan, 2017; Lin, Yu, Wu, and Cheng, 2017) and operating methods.

(7) Internal structure of the organization, consisting of company strategy (Derun, 2013; Edvinsson; Malone, 1998), technology, and organizational structure (Popov; Vlasov, 2018; Ritvanen; Sveiby, 2017), with the items: company strategy (Stewart, 1994; Xu; Liu, 2019) and technology.

(8) External structure of the organization, classified by relationships with contractors and competitors, trademarks (Mouritisen, 1998; Nascimento; Souza Junior, 2019), moral and ethical values of the entities (Derun, 2013; Edvinsson; Malone, 1998), and employees, containing the items: moral, social, financial, economic (Foerster; Pierre-Daniel; Mark, 2011; Makrominas, 2017; Malavski; Lima; Costa), and environmental values.

For Malavski, Lima, and Costa (2010), the measurement of intellectual capital follows a rational logic established in the following order: (I) Capabilities represented by processes, skills, and execution; (II) Resources characterized by operational, strategic, and tactical activities; and (III) Competencies represented by the development of skills.

If the organization does not develop the necessary skills in its human and material resources, a loss and destruction of value will occur (Malavski; Lima; Costa, 2010; Mouritsen, 1998; Ritvanen; Sveiby, 2017; Stewart, 1994), reflected in the reduction of competencies (Bontis, 2001; Edvinsson; Malone, 1998; Foerster; Pierre-Daniel; Mark, 2011), consequently causing a decrease in available resources and its results. Therefore, the intended use and reuse of available resources and inputs from an economic, social, and ecological perspective (Nascimento; Souza Junior, 2019; Popov; Vlasov, 2018; Xu; Liu, 2019) impact costs, revenues, and expenses, and can lead to benefits, profit, or losses (Derun, 2013; Makrominas, 2017; Martins, 2012; McGrattan, 2017).

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The literature shows that adopting a management model applied to the life cycle will provide the company with business improvement and evolution in using its available resources.

The vision based on knowledge and available resources provides a competitive advantage in a company, characterized as both tangible and intangible. Companies have many resources (e.g., human, financial, organizational, physical, and technological), but few are considered strategic (JUGDEV, 2007).

The literature has not evidenced any relationship between the impact of the eight guidelines and the 21 items that make up the intellectual capital on the four phases of the product life cycle applied to the construction industry, and there is no relationship between the intellectual capital and how they influence the lifecycle phases.

Following what was presented for intellectual capital, concepts, and applicability, the proposed management model was developed regarding the attribution of qualitative value to the four aspects related to the products' life cycle, as shown below:

From the eight guidelines, it was possible to identify the 21 items that make up the intellectual capital, according to the literature studied:

According to Filatotchev (2009), companies now do not depend on good results to translate organizational effectiveness and efficiency. Rather, they need to understand and measure the expected results, adding the intangible resources allocated to obtaining the results and how they evolve.

For Matschewsky *et al.* (2016), it is up to business management to promote and provide a safe, efficient, and effective environment within its organizational theme for the company that, at the same time, scales, manages, and organizes the aspects inherent to the expected results from the tangible and intangible resources at its disposal.

We realize that the relevant factor is not only a demand, i.e., tangible resources that add value to the business; rather, it is the customer's perception and experience that will guide the company on how to understand the product and its acceptance, and this can change considerably, or even totally, what to produce, how to produce, and when to produce.

Kirkwood (2016) argues that sizing the lifecycle cost in its stages, from its installation to its disposal, provides managers and stakeholders with a holistic view of the business from the product's useful life and, consequently, efficient and effective management, leading to a satisfactory result.

According to Kirkwood (2016), it is necessary to build a historical basis from the costs used in the composition of products, evaluating the possibilities for optimization and continuous reduction of consumption and resource use, also pointing to the consideration in these composition models that involve costs with a sustainable bias.

Research and development expenses represent an intangible asset for companies, many of which originate from environmental issues and new products and processes (Matschewsky *et al.*, 2016). Therefore, it would not only be considered as costs related to the economic aspect of the products but also those related to their elimination and disposal (Kirkwood, 2016).

Thus, it can be seen that intangible assets classified as environmental assets by companies are premised on controlling, preserving, and restoring the environment (Matschewsky *et al.*, 2016).

The return on investment translates into the economic and financial desires of companies. Thus, creating sustainable value brings a qualitative and quantitative return for companies, consequently enhancing their image and reputation toward stakeholders, intertwined with efficient management and added value formed through companies' intellectual and human capital.

While providing value to its shareholders, the company can also provide education, culture, leisure, and social justice to the community and protect diversity and ecosystems, thus striving for sustainability (Vellani, 2011).

Capatina (2019) presents green intellectual capital, green structural capital, and green relational capital as integral parts of business philosophy, representing a corporate culture that values cleaner production with environmentally friendly products. Such a posture now aligns sustainability by managers as a preponderant factor in corporate decision-making. Another extremely relevant factor in this process is that entities' competitive advantage represents sustainability.

The company can prescribe and subvert this understanding as much as possible and aims to provide stakeholders with economic value, the society with social value, and the environment with sustainable value.

CONCLUSION

At the end of the 1990s, many researchers published important articles on intellectual capital and the life cycle. As of the 2000s, we observed an increase in the number of works seeking to establish relationships between intellectual capital and lifecycle management.

Strategic Alliance	DIMMERS - (D)	FACTORS - (F)	GUIDELINE - (Di)	LIFE CYCLE STAGES - (LCF)
	(1d) Human Capital (Training, Skills, and Competencies) **(2d) Relational Capital** (Stakeholders) **(3d) Structural Capital** (Organization, Clients, and Suppliers)	**(1f) Financial Management** **(2f) Process Management** **(3f) Client Management** **(4f) Resource and Development Management and Renewal**	(01 Di) - Stewart, 1997; Sanches, 2000; Kozirev, 2003; Joia, 2000. (02 Di) - Leontiev, 2002. (03 Di) - Brooking, 1996. (04 Di) - Malone, 1997. (05 Di) - Edvinsson, 1997. (06 Di) - Bazylevych, 2008. (07 Di) - Albert, 1996. (08 Di) - Rodov, 2002.	(1stFCV) - **Planning** (2ndFCV) - **Construction** (3rd LCA) - **Use and Maintenance** (4thLife Cycle Cycle) - **Disposal and Retrofit**

Chart 7. Model of the impact of intellectual capital on the four phases of the product life cycle

Source: Adapted from Antunes; Mucharreira (2015); Assaf Neto (2017); Bontis (2001), Colauto and Mambrini (2006); Derun (2013), Edvinsson and Malone (1998); Fazlagić (2005); Foerster et al. (2011); Göktepe-hulten (2010); Iudícibus (2017); Makrominas (2017); Malavski et al. (2010); Martens (2008); Martins (2012); McGrattan (2017); Mouritisen (1998); Nascimento and Souza Junior (2019); Popov and Vlasov (2018), Stewart (1994); Ritvanen; Sveiby (2010); Xu and Liu (2019)

Product Lifecycle Management Model								
Knowledge Management								
Scaling	Factor	Intellectual Capital			Lifecycle Stages			
Capital	Management	Guidelines	Itens		1	2	3	4
(1D) - Human	(2f) Processes	1 Di	1	Human Resources				
			2	Skills				
			3	Competencies				
			4	Development				
		2 Di	5	Knowledge				
			6	Experience				
	(1f) Financial	3 Di	7	Organizational Structure				
			8	Corporate Culture				
		4 Di	9	Intangible Assets				
(2D) - Relational	(3f) Clients	5 Di	10	Customer Assets				
			11	Trademarks and Symbols				
			12	Copyrights				
		6 Di	13	Company Database				
			14	Methods of Operation				
(3D) – Structural	(4f) Resource Renewal and Development	7 Di	15	Company Strategy				
			16	Technology				
		8 Di	17	Moral Values				
			18	Social Values				
			19	Financial Values				
			20	Economic Values				
			21	Environmental Values				

Chart 8. Management model

Source: Prepared by the authors (2021)

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This movement has attracted more studies to develop the theme, leading some journals to begin a more precise approach to the subject, highlighting the Journal of Cleaner Production, which concentrates an important number of articles on lifecycle management at construction sites and related to eco-efficiency assessment as a management and quality tool, along with the International Journal of Lifecycle Assessment.

The network of co-authors and countries demonstrates the consolidation of cooperation and collaboration among the various research centers to develop science and technology in the interdisciplinary fields of sustainability, intellectual capital, and lifecycle assessment. Through bibliometric study, it was possible to identify eight guidelines and the 21 items that comprise the intellectual capital; however, no findings identified their degree of impact and influence in each of the four phases of the life cycle of products employed in the construction industry. The study allowed the understanding of the main thematic areas and intellectual capital, its eight guidelines in their 21 items, and the four life cycle phases.

One of the research findings was the importance of intellectual capital in the management of human resources and the impact of its development on value generation in companies. This is configured as knowledge-based management, and intellectual capital is the main asset available to companies.

Another relevant fact is that knowledge management is translated into market vision and corporate value. The greater the intellectual capital of the organizations, the greater will be the concern with social, environmental, and economic aspects and the formation of available resources. As a result of knowledge accumulation, the 21 items comprising the eight intellectual capital guidelines generate qualitative and quantitative values for the business, defining it as a competitive advantage. Disregarding and not managing this can affect and bring losses to the business.

We verified an important number of studies focused on developing evaluation models for intellectual capital aligned to strategic business management and knowledge management, but without verifying the impact degree on the phases of the life cycle, as mentioned.

Regarding the eight guidelines' influence on their 21 intellectual capital items in each of the lifecycle phases applied to the construction industry, the absence of management models that analyze and determine the impact and influence degree in each of the lifecycle phases was noticed.

Endnotes

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5 Free software, avaiable at: www.vosviewer.com. Acessed on: 04/10/2021

6 This is in accordance with the systematic literature review carried out by the authors studied in the bibliometry, namely: (Stewart, 1994; Mallone, 1998; Mouritisen, 1998; Sveiby, 1999; Bontis, 2001; Antunes, 2015; Fazlagić, 2005; Colauto and Mambrini, 2006; Martens, 2009; Hulten, 2010; Foerster, 2011; Malavski, 2010; Martins, 2012; Derun, 2013; Makrominas, 2016; McGrattan, 2017; Vedachedu, 2017; Junior and Oliveira, 2017; Popov and Vlasov, 2018; Xu and Liu, 2019).

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Received: January 18, 2022

Approved: January 28, 2022

DOI: 10.20985/1980-5160.2022.v17n1.1771

How to cite: Almeida, L.S.F., Salles, M.T., Vieira Neto, J. (2022). The influence of intellectual capital on value creation in the life cycle: a bibliometric study. Revista S&G 17, 1. https://revistasg.emnuvens.com.br/sg/article/view/1771