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RESEARCH PAPER

Industry 4.0 and 5g technology on firms network: a balanced competitive expansion conceptual model development

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ABSTRACT

Goal: This study aims to explore the relationship between companies leveraged by the use of 5G technologies and Industry 4.0 to develop a model that explains the impacts on the ecosystem.

Design / Methodology / Approach: This study applies a bibliometric research utilizing scientometric review to provide an understanding of the status quo and the trend for research on the tripod theme in the world: (a) Firm Network, (b) Industry 4.0 and (c) 5G Technology. The study is extended by a qualitative research applying critical incident technique to experts´ interviews looking for the gap in the bibliometric review and insights on the tripod theme to develop a Conceptual Model based on grounded theory.

Results: A conceptual model of balanced competitive expansion of the market was developed regarding the bibliometric and qualitative research. The model, based on 5 hypotheses - related to Partnership, Competition and Products and Services – highlights that while the 5G technology and Industry 4.0 impact the relationship among companies (competition, partnerships, product and services) this impact is balanced with a market expansion.

Limitations of the investigation: This proposed conceptual model must be evaluated with quantitative research to validate the variables and hypothesis developed based on grounded theory.

Practical implications: This paper shows methodological steps and basis to develop a conceptual model to be validate with broadly quantitative survey.

Originality / Value: The paper demonstrates its originality and relevance by presenting a model relating innovative technology trends and their impact in the ecosystem.

Keywords: Firm network; Industry 4.0; 5G Technology; Mixed research; Competition model.

1. INTRODUCTION

Much is expected of what 5G technology is expected to impact the market and people"s lives. Its evolution (from 4G to 5G) is not only based on the overall increase in network capacity for the mobile phone user, but on the adoption of complex and often requirements for the same end user (NGMN, 2015). In addition to this technically challenging requirements for the same end user (NGMN, 2015). In addition to this technically challenging context, unlike the definition of attenuating generations promoted by technology-driven entities (3GPP), the fifth generation was conceived by the Next Mobile Generation Network (NMGN) alliance of not only operators, but also manufacturers, industries, research institutes seeking to set technical

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and functional standards for what new technology should provide. More recently, industry-specific industry associations - for example 5GAA (5G Automotive Association) - have formed and entered into this context, increasing and diversifying the actors in this ecosystem.

That is, the entire vertical and horizontal production chain (suppliers, system integrators, industries, distributors and consumers) should be impacted by defining new relationships, opportunities and threats (Alhuseini and Olama, 2019).

In this context, it is important to seek opportunities to identify and explain the possible impact on the competitive relationship model within industry segments by connecting with Industry 4.0 through the introduction of 5G technology and its technical and functional requirements.

The purpose of this study is to identify apply a bibliometric research utilizing scientometric review to provide an understanding of the status quo and the trend for research on the tripod theme (Firm Network, Industry 4.0 and 5G Technology) in the world.

The bibliometric research (list of authors, co-authors and institutions) shows the presence of technology companies working together with the academic space, which indicates the efforts in research and development of companies involved in the development of the Industry 4.0 ecosystem and 5G Networks

While Nix et al. (2004) identifies the requirements for successful collaboration between independent companies, reinforcing the concept of Business Networks as a success factor, Carnovale, S. et al. (2016) in their work, highlights the relationship between firms in the globalized world, boosting Partnerships supported by capital funds such as Joint Ventures. The concept of Business Network emphasizes how, by interacting with each other, companies can share resources, thus achieving greater capacity and workload flexibility (Hines, 1994). In this concept, RL Chapman and M. Corso (2005) develop the theme of inter-company collaboration and innovation in networks as an action of continuous improvement in which a company can obtain competitive advantages (Competition) by looking outside its borders and establishing close relationships with other companies. They emphasize that collaboration between companies and the development of company networks in many of our traditional networks and emerging industry sectors are recognized as essential requirements for competitive success. Considering an industry network with a group of firms that expressly agree to cooperate in some way and depend on each other (Rosenfeld 1995), Antonelli and Caroleo (2012) point out that there is a need for a reliable and impartial method aimed at identification and analysis of collaborative patterns within a network of industries as it points out that not all collaborative actions bring immediate (and measurable) economic benefits to determine their presence and effectiveness. They emphasize that business-to-business collaboration and the development of business networks in many of our traditional networks and emerging industry sectors are recognized as essential requirements for competitive success.

Galang (2014) explores the concept of early adopters and emphasizes how the pace of technology adoption is determined at three levels: at the knowledge, institutional and organizational levels.

The expected benefits of 5G technology can be mapped into requirements called use cases (use case) according to NGMN (2015) in which M. Karrenbauer et al (2019) highlight groupings of these use cases in classes to understand the impact on industries: (a) Infrastructure retrofit; (b) robots with mobile connectivity; (c) inbound logistics for manufacturing, flexible and modular assembly area.

Considering the IoT technology (one of the pillars of Industry 4.0) leveraged with the 5G technology, the view of French and Shim (2016) brings the concept of SIoT (Social IoT) as a theoretical concept under development of a network following human social networks. While Kantorla et al. (2017) also highlight the exponential increase in expected interrelationships with 5G and the need for models and methods of collaboration between ecosystem entities in order to safely enhance the relationship.

While the articles address the tripod theme, they do not explore the relationship between the topics and miss to identify the competition and market model impact related to the Industry 4.0 and 5G technologies adoption.

Qualitative research was applied to 10 experts in Brazil to collect more critical items related to the tripod theme. Based on the lexical analysis on the transcript interviews, we look for the gap in the bibliometric review and suggestion for new studies.

As part of the exploratory phase, qualitative research was applied to 10 experts in Brazil to collect more critical items related to the tripod theme through questions related to four main concepts (Industry 4.0 and 5G in the production chain, partnerships, 5G as an Industry 4.0 enabler, and competition) based on their experience in the industry in which they work, and on their evolution from new technologies, what impressions (gaps, trends, insights) on scenarios that may touch the theme studied.

Based on the lexical analysis on the collected data from the interviews, a study was carried out using the Grouded Theory methodology from Glaser and Strauss (1967) and Marchisotti (2021), to develop the conceptual model of balanced competitive expansion to be studied and validated.

The paper is organized as follows: the next section outlines the bibliometric methods to collect and refine the articles database. The next section explains the process and the results of bibliometric analysis based on EndNote, NVivo and VOSviewer tools functions on frequent words, keywords, authors, co-authors and institutions. Finally, based on grounded theory the qualitative research and bibliometric analysis were input to develop hypothesis and a conceptual model prepared to a quantitative.

2. METHODS AND MATERIALS

The methodological elements support the research strategy following the steps (**Figure 1**) starting from the definition and deepening of the understanding of the bibliographic research), hence applying research methodology through interviews with Critical Incident Specialists (Critical Incident Technique) that allows the identification of gaps, problems and relationships as input for the design of a grounded theorist.

The bibliographic research is used to survey the state of the art on the themes under study produced by the scientific community to support the identification of points that deserve further investigation by this work and that are inputs for hypotheses to be investigated.

Extending the exploratory phase, field research is applied, through interviews with experts, to seek impressions (gaps, trends, insights) about scenarios that may touch on the studied theme. This phase is based on the Critical Incident Technique (TIC) which uses a set of procedures to collect direct observations of human behavior, aiming to facilitate the resolution of practical problems (Flanagan, 1954).

Grounded Theory (Glaser and Strauss, 1967) developed from bibliographic and field research, thus developing a conceptual model for broader research.

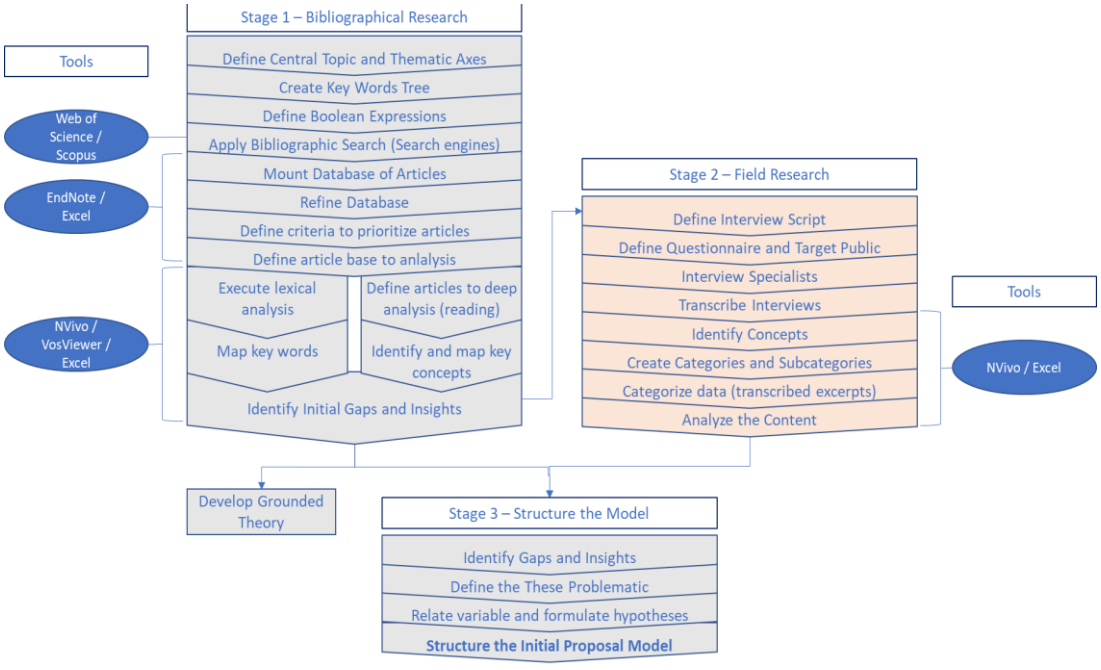

Figure 1. Work steps.
Source: Authors.

3. BIBLIOMETRIC RESEARCH

Unit Of Analysis

The selected unit of analysis is all documents about the theme “Potential impact from Industry 4.0 and 5G Technology on relations among firms” tailored in a search tripod - Firm Network, Industry 4.0 and 5G Technology. Each search subject is associated a group of subthemes as **Figure 2**.

The exploratory search using the search engines of the SCOPUS and Web of Science databases, by the thematic axes, allowed the extraction of 1578 articles (**Table 1**).

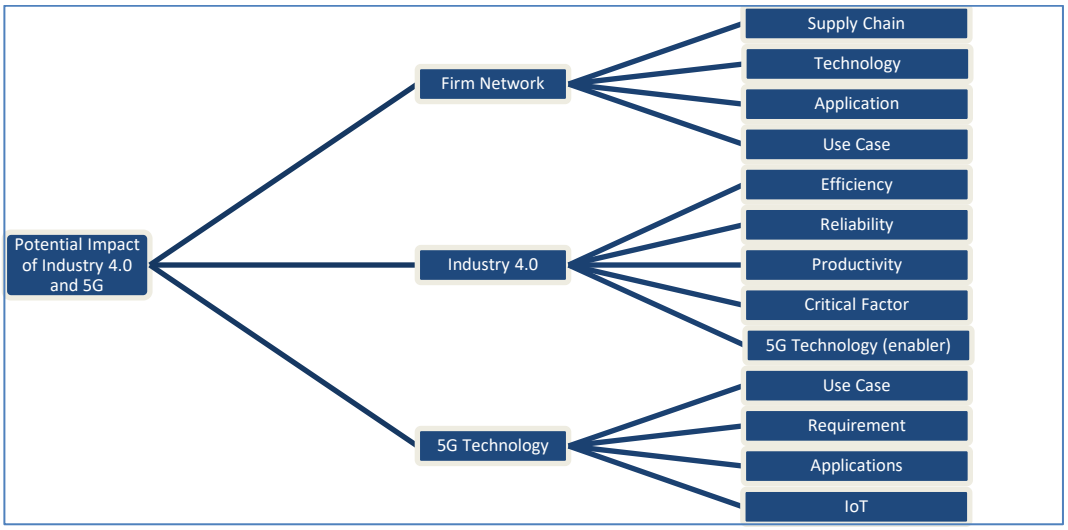

Figure 2. Tripod subject.
Source: Authors

Table 1. Search Queries.

Subject	Source	Query	Result
Firm Network	Scopus	(**TITLE-ABS-KEY** (("company network" OR "enterprise network" OR "firm network" OR "firms network" OR "organization cluster") AND ("supply chain" OR technology OR application OR "use case"))) AND **PUBYEAR** > 2004 AND (**EXCLUDE** (SUBJAREA , "MATH") OR EXCLUDE (SUBJAREA , "PHYS") OR EXCLUDE (SUBJAREA , "ARTS") OR EXCLUDE (SUBJAREA , "MEDI") OR EXCLUDE (SUBJAREA , "CENG") OR EXCLUDE (SUBJAREA , "BIOC") OR EXCLUDE (SUBJAREA , "CHEM") OR EXCLUDE (SUBJAREA , "HEAL") OR EXCLUDE (SUBJAREA , "NEUR") OR EXCLUDE (SUBJAREA , "PHAR") OR EXCLUDE (SUBJAREA , "NURS") OR EXCLUDE (SUBJAREA , "VETE") OR EXCLUDE (SUBJAREA , "IMMU") OR EXCLUDE (SUBJAREA , "Undefined")) AND (**LIMIT-TO** (DOCTYPE , "ar")) AND (**LIMIT-TO** (LANGUAGE , "English"))	298
	Web of Science	(**TS**= ((((“company network” OR “enterprise networks” OR “firm network” OR “firms network” OR “organization cluster”) AND (“supply chain” OR “technology” OR "application" OR "use case"))))) AND **LANGUAGE:** (English) AND **DOCUMENT TYPES**: (Article) **Refined by: [excluding]** RESEARCH AREAS: (ELECTROCHEMISTRY OR GENERAL INTERNAL MEDICINE OR MATHEMATICS OR GEOGRAPHY OR OPTICS OR INSTRUMENTS INSTRUMENTATION OR PHYSICS OR MATHEMATICAL METHODS IN SOCIAL SCIENCES) **Timespan:** 2005-2019. **Indexes:** SCI-EXPANDED, SSCI, AandHCI, CPCI-S, CPCI-SSH, ESCI.	86

Industry 4.0	Scopus	**TITLE-ABS-KEY** ("industry 4.0" AND (efficiency OR reliability OR "cost reduction" OR cfs OR "Critical Factor" OR 5g OR "fifth generation")) AND **PUBYEAR** > 2004 AND (**EXCLUDE** (SUBJAREA , "MATH") OR EXCLUDE (SUBJAREA , "PHYS") OR EXCLUDE (SUBJAREA , "ARTS") OR EXCLUDE (SUBJAREA , "PSYC")) AND (**LIMIT-TO** (LANGUAGE , "English")) AND (**LIMIT-TO** (DOCTYPE , "ar"))	249
	Web of Science	(**TS**=((("industry 4.0" AND (efficiency OR reliability OR "cost reduction" OR (CFS OR "Critical Factor") OR ("5G" OR "fifth generation"))))) AND **LANGUAGE:** (English) AND **DOCUMENT TYPES:** (Article) **Refined by: [excluding]** WEB OF SCIENCE CATEGORIES: (THERMODYNAMICS OR BIOTECHNOLOGY APPLIED MICROBIOLOGY OR MATHEMATICAL COMPUTATIONAL BIOLOGY OR MEDICAL INFORMATICS OR MINING MINERAL PROCESSING OR MATHEMATICS INTERDISCIPLINARY APPLICATIONS OR NUCLEAR SCIENCE TECHNOLOGY OR POLYMER SCIENCE OR PHYSICS APPLIED OR OPTICS OR WATER RESOURCES) **Timespan:** 2005-2019. **Indexes:** SCI-EXPANDED, SSCI, AandHCI, CPCI-S, CPCI-SSH, ESCI.	201
5G Technology	Scopus	**TITLE-ABS-KEY** ((("5G technology" OR "5G network" OR "fifth generation network")) AND ("use case" OR "requirement" OR "application" OR (iot OR "Internet of Things"))) AND **DOCTYPE** (ar) AND **PUBYEAR** > 2004 AND (**LIMIT-TO** (LANGUAGE , "English")) AND (**EXCLUDE** (SUBJAREA , "MATH") OR EXCLUDE (SUBJAREA , "CHEM") OR EXCLUDE (SUBJAREA , "BIOC") OR EXCLUDE (SUBJAREA , "ARTS") OR EXCLUDE (SUBJAREA , "HEAL") OR EXCLUDE (SUBJAREA , "PHAR"))	633
	Web of Science	(**TS**= ((("5G technology" OR “5G network” OR “fifth generation network”)) AND ("use case" OR "requirement" OR "application" OR (IoT OR “Internet of Things”)))) AND **LANGUAGE:** (English) AND **DOCUMENT TYPES**: (Article) **Refined by: [excluding]** RESEARCH AREAS: (OPTICS OR CHEMISTRY OR PHYSICS OR ELECTROCHEMISTRY OR MATHEMATICS) **Timespan:** 2005-2019. **Indexes:** SCI-EXPANDED, SSCI, AandHCI, CPCI-S, CPCI-SSH, ESCI.	111
			1.578

Source: Authors

Base Purge Process

Regarding the methodology proposed by Treinta et al. (2014), after evaluating basic concepts related to Firm Network, Industry 4.0 and 5G Technology, the following retrieval codes were used on both database collections to identify only document type articles written in English: 1- ((“company network” OR “enterprise networks” OR “firm network” OR “firms network” OR “organization cluster”) AND (“supply chain” OR “technology” OR "application" OR "use case")); 2- ("industry 4.0" AND (efficiency OR reliability OR "cost reduction" OR (CFS OR “Critical Factor”) OR (“5G” OR “fifth generation”))) and 3- (("5G technology" OR “5G network” OR “fifth generation network”)) AND ("use case" OR "requirement" OR "application" OR (IoT OR “Internet of Things”)). Were excluded from the source search, articles from the subject areas considered irrelevant to the theme.

The total of 1578 articles were extracted and were exported and uploaded on EndNote®

software, where we followed the following steps to refine this database collection for each subject (quantity result in **Table 1**): a – Extraction; b – Import/Upload to EndNote with automatic duplicated articles remove; c – Manual removal of remaining duplicated articles; d – Purge of articles with missing information (author, journal, year, keywords, abstract, pdf); e – Purge of articles considered irrelevant to the theme; f – Articles consolidation from the three subjects; g – Manual removal of remaining duplicated articles.

Following the hereinbefore described steps, we excluded 192 articles from Firm Network subject, 145 articles from Industry 4.0 subject and 343 articles from 5G Technology subject whose content address specific subject with low correlation with the tripod subject study (**Table 2**) resulting the evolution of timeline publication of the selected articles as shown in **Figure 3**.

Table 2. Base Refinement

			Base purge						
		Data Collection	Duplicated (automatic)	Duplicated (manual)	Lack of information (author, journal, year, keywords, abstract, pdf)	Out-of-scope (Title, Keywords and Abstract)	Selected by Theme	Duplicated (manual)	Selected
Subject 1 - Firm Network	Scopus	298	38	25	71	192	58	-	-
	Web of Science	86							
Subject 2 - Industry 4.0	Scopus	249	79	46	49	145	131	2	333
	Web of Science	201							
Subject 3 - 5G Technology	Scopus	633	39	44	172	343	146	-	-
	Web of Science	111							
		1578	156	115	292	680	335	2	333

Source: Authors

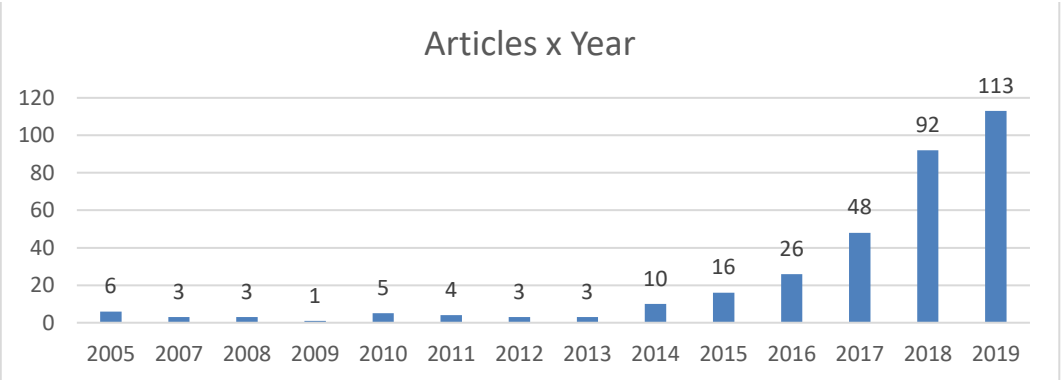

Figure 3. The number of articles related to the triple constraint (Firm Networks, Industry 4.0 and 5G Technology)
Source: WOS and SCOPUS core collection after refinement 2005-2019

Based on the refinement series, we forward 333 articles to lexis analysis with NVivo and VOSviewer tools.

The Figures: **Figure 5** - Network of co-occurring keywords; **Figure 6** - Item Density

Visualization of co-occurring keywords, **Figure 7** - Network Visualization of co-authorship, and **Table 3** - 20 most frequent co-occurring keywords were generated using VOSviewer®.

The EndNote software allows that a database collection be exported in different output styles. We have executed a complete database export in ".xml" format and imported it on Microsoft Excel. Microsoft Excel was used to support the data totalization and information formatting for articles x year, most productive authors, co-authors and top source journals. To support our bibliometric analysis, we have also selected NVivo - the most used qualitative and mixed-methods data analysis software tool and VOSviewer - a software tool for constructing and visualizing bibliometric networks. These networks may for instance include journals, researchers, or individual publications, and they can be constructed based on citation, bibliographic coupling, co-citation, or co-authorship relations.

Words and keywords frequency

With NVivo we executed the functions:

i. "Word frequency" – applied to all 333 articles (PDF) to identify the most frequent words, applying the following parameters: minimum length of 7 letters avoiding adverbs and pronoun on the query result, with extension to derivate words (**Table 4**), and restricting to display only the 1000 most frequent.
ii. "Word Cloud" - capture the result as word cloud visualization (**Figure 4**).
iii. "Word frequency" – applied to the 10 interview Portuguese transcripts (Word) to identify the most frequent words, applying the following parameters: minimum length of 7 letters avoiding adverbs and pronoun on the query result, considering exact words (no derivate function) and restricting to display only the 1000 most frequent.
iv. "Export" the interview 20 most frequent words to Excel (**Table 6**) to translate to English and map to the other frequent words and keywords collections.

For keywords frequency analysis, we have also chosen VOSviewer software to execute the function "create a map based on text data" with following parameters:

i. Data source: "Read data from reference manager files", choosing a previous exported file from EndNote containing the reference information of all articles.
ii. Fields from which terms will be extracted: "Title and abstract fields"
iii. "Ignore structured abstract labels"
iv. "Ignore copyright statements"
v. counting method: "full counting"
vi. Minimum number of occurrences of a keyword: "10"
vii. Number of keywords to be selected = 1000

The keywords are extracted from the titles and abstracts of each article. We can see this data on **Table 3** the 20 most frequent keywords with their occurrences counting and on **Figure 5** and **Figure 6** we can see the "Network of co-occurring keywords" and "Item density visualization of co-occurring keywords". In co-occurrence analysis of keywords, the relatedness of items is determined based on the number of documents in which they occur together. The higher the number of cooccurrence of two terms, closed they will be located close to each other on the map where the colors indicate how nodes are distributed in the two-dimensional space underlying the visualization.

In the network visualization, items are represented by their label and by default also by a circle. The size of the label and the circle of an item is determined by the weight of the item, this indicates the number of publications that have the corresponding term in their title or abstract. The higher the weight of an item, the larger the label and the circle of the item. For some items the label may not be displayed. This is done in order to avoid overlapping labels. The color of an item is determined by the cluster to which the item belongs. (N.J. Van Eck, L. Waltman, 2014).

VOSviewer has grouped the terms into 6 clusters, of which three are of significant size. The red cluster consists of firm network terms. The blue cluster covers terms related to Industry 4.0, the green cluster consist of terms related to 5G Technology.

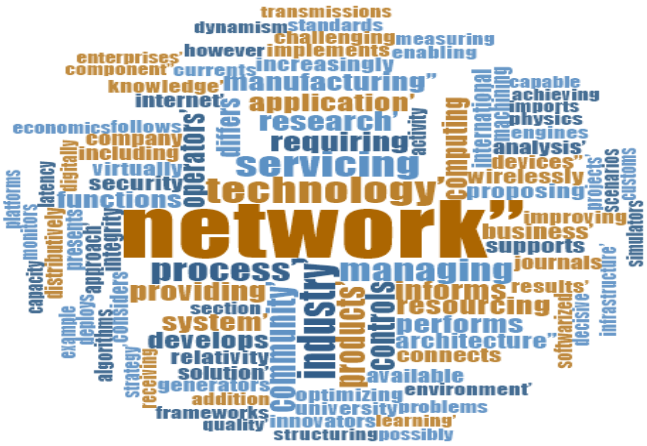

Figure 4. Most frequent words ("Word cloud view" – generating using NVivo©)
Source: Authors

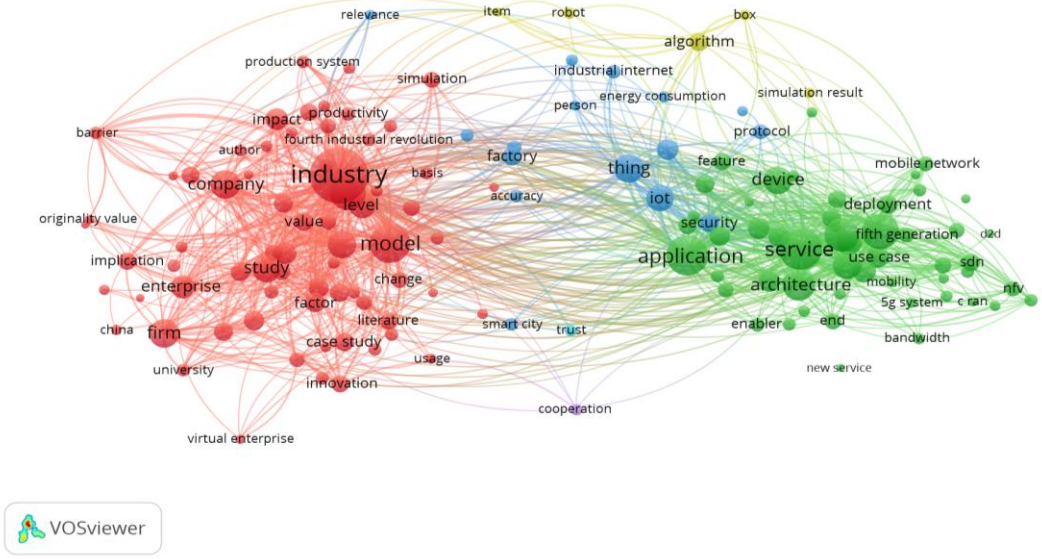

Figure 5. Network of co-occurring keywords.
Source: Authors

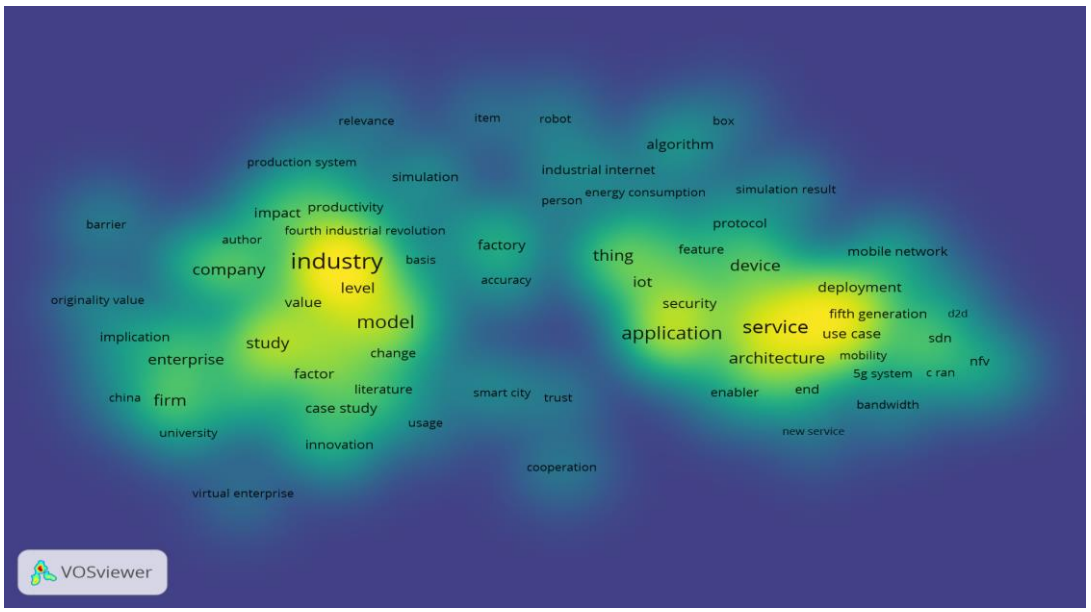

Figure 6. Item Density Visualization of co-occurring keywords.
Source: Authors

Table 3. 20 most frequent co-occurring keywords (VOSviewer©).

#	Word	Occurrence
1	industry	390
2	service	211
3	application	199
4	model	190
5	5g network	155
6	process	148
7	requirement	135
8	architecture	115
9	company	101
10	firm	101
11	thing	100
12	research	98
13	device	97
14	study	96
15	communication	93
16	iot	87
17	level	79
18	scenario	75
19	user	69
20	enterprise	67

Source: Authors

Words and keywords map analysis

In **Table 5**, we have mapped the 20 most frequent words in Articles database, collected from all 333 articles (PDF) through NVivo "Word Frequency" function, with the other three sources of relevant terms to the theme: (a) keyword code used in the WOS and Scopus search, (b) most frequent co-occurring keywords (VOSviewer analysis from title and abstract content), and (c) most frequent words from qualitative research (interview transcriptions).

Note that the word "managing" (5th more frequent) with 8158 occurrences and "control" (8th more frequent) with 6766 occurrences are not present in the 20 most frequent words collected from the other sources. The words "community", "resourcing", "system", and "perform" are mapped only with one of the three other sources.

In **Table 6**, we have mapped the 20 most frequent words in the qualitative research with the keyword code used in the WOS and Scopus search. The words "people", "process" and "potential" are not mapped with keyword code used in database search.

Table 4. 20 most frequent words in Articles database grouped by similarity or derivation based on NVivo function.

Word	Similar/Derivate words
network""	network, network", network"", networked, networking, networks, networks", networks", networks""
technology"	technolog, technologes, technologi, technologic, technological, technological", technologically, technologies, technologies", technologies"", technology, technology"
industry"	industrial, industrial", industrial"", industrialism, industrialization, industrialized, industrially, industrials, industrie, industries, industries", industry, industry"
Servicing	service, service", service"", serviceability, serviced, services, services", services"", servicing
Managing	manageability, manageable, managed, management, management", managements, manager, managers, managers", managers", manages, managing
process"	process, process", processed, processes, processes", processing,

	processing”
products”	product, product”, production, production”, productions, productive, productively, productivities, productivity, products, products”, products””
community”	communal, communicate, communicated, communicates, communicating, communication, communication”, communication””, communications, communications”, communicative, communicator, communism, communities, communities””, community, community”
Controls	control, control””, controllability, controllable, controlled, controller, controllers, controllers”, controlling, controls
Requiring	require, required, requirement, requirements, requirements”, requires, requiring
research”	research, research”, researched, researcher, researchers, researchers”, researchers”, researches, researching, researchs
Informs	informal, informal”, informally, informant, informants, informants”, information, information”, informational, informative, informe, informed, informes, informing, informs
Providing	provide, provided, providence, provider, providers, providers”, provides, providing
application”	applicability, applicable, applicant, applicants, application, application”, applications, applications”, applicative
Resourcing	resource, resource””, resourced, resourceful, resourcefully, resourcefulness, resources, resources”, resourcing
operators”	operability, operable, operate, operated, operates, operating, operating””, operation, operation”, operational, operationally, operations, operations”, operations””, operative, operatives, operator, operator””, operator”snetworksthat, operators, operators”, operators”networks
Computing	computability, computable, computation, computational, computationally, computations, compute, computed, computer, computers, computes, computing, computing”, computing”57
system”	system”, system””, system”soverall, systeme, systemes, systemic, systemicness, systems, systems”, systems”, systems””
Performs	perform, performance, performance”, performances, performant, performed, performer, performers, performing, performs
manufacturing””	manufactur, manufacturability, manufacture, manufactured, manufacturer, manufacturers, manufacturers”, manufactures, manufacturing, manufacturing”, manufacturing””, manufacturings

Source: Authors

Table 5. 20 most frequent words in Articles database (NVivo©) mapped to search keywords, most frequent co-occurring keywords (title, abstract and keywords), and mapped to most frequent words from qualitative research.

Word	Occur.	Map to keyword code used in search	Map to frequent co-occurring keywords	Map to frequent words in qualitative research
network””	28771	5G Network	5G Network	No Map
technology”	10558	5G Technology	Architecture	Technology
industry”	10279	Firm	Industry	Industry
servicing	9925	Use Case	Service	No Map
managing	8158	No Map	No Map	No Map
process”	8118	No Map	Process	Process
products”	7529	Productivity	No Map	Product
community”	7386	No Map	No Map	People
controls	6766	No Map	No Map	No Map
requiring	6284	Requirement	Requirement	No Map
research”	6202	No Map	Research	No Map
informs	5967	No Map	Communication	Information
providing	5932	Use Case	Service	No Map
application”	5704	Application	Application	No Map
resourcing	5694	Supply Chain	No Map	No Map
operators”	5688	5G Network	Communication	Telecom

computing	5623	5G Technology	No Map	No Map
system"	5594	Application	No Map	No Map
performs	5570	Efficiency	No Map	No Map
manufacturing""	5409	Industry 4.0	Industry	No Map

Source: Authors

Table 6. 20 most frequent words in in qualitative research mapped to keyword code used in the article search.

Word	Occurrence	Map to keyword code used in search
industry	185	Direct Map
enterprises	155	Direct Map
technology	110	Direct Map
information	77	Indirect Map (Technology)
people	45	No Map
impact	44	Indirect Map (Requirement)
capacity	42	Indirect Map (Requirement)
market	37	Indirect Map (Firm Network)
business	30	Indirect Map (Firm Network)
product	53	Direct Map
partnerships	48	Indirect Map (Firm Network)
relationship	27	Indirect Map (Firm Network)
factors	26	Direct Map
process	26	No Map
potential	25	No Map
telecom	22	Indirect Map (Organization Cluster)
competition	17	Indirect Map (Firm Network)
development	17	Indirect Map (Efficiency)
security	17	Indirect Map (Reliability)
velocity	17	Indirect Map (Requirement)

Source: Authors

Author and co-author

Table 7 presents the top 7 most productive authors. Jaber, M.(University of Surrey); Rao, S. K.(Tata Consultancy Services Ltd); Nightingale, J.(University of the West of Scotland); Afolabi, I. (Aalto University); Wan, J. F.(South China Univ Technol); Banyai, T. (Univ Miskolc); Zhang, J.(China Telecom Co.). Note the presence of technology companies (Tata Consultancy and China Telecom) in this list indicating the firm efforts to be part of the research and study ecosystem related to the new technologies (Industry 4.0 and 5G Networks).

Table 8 presents the top 12 most productive co-authors. Wang, Y.(Plymouth University); Tafazolli, R. (University of Surrey); Vasilakos, A. V. Lulea (University of Technology); Wang, H. (GoPerception Laboratory), occupied the top 4 positions, where half has firm presence.

A co-authorship network was generated using VOSviewer, for authors with a minimum of 2 articles, is presented in **Figure 5.** Network of co-occurring keywords, where we could identify 27 authors, divided in 3 clusters or a research community. Each circle/node represents a researcher, large circles represent researchers that have many publications. Small circles represent researchers with only a few publications. In general, the closer two researchers are located to each other in the visualization, the more strongly they are related to each other based on bibliographic coupling. (Van Eck NJ and Waltman L, 2014).

Table 7. The top more most productive authors with more than one publication.

Author	Institution	Country	Occurrence
Jaber, M.	University of Surrey	United Kingdom	2
Rao, S. K.	Tata Consultancy Services Ltd	India	2
Nightingale, J.	University of the West of Scotland	United Kingdom	2
Afolabi, I.	Aalto University	Finland	2
Wan, J. F.	South China Univ Technol	China	2
Banyai, T.	Univ Miskolc	Hungary	2
Zhang, J.	China Telecom Co.	China	2

Source: Authors

Table 8. The top productive co-authors with more than two publications.

Co-Author	Institution	Country	Occurrence
Wang, Y.	Plymouth University	United Kingdom	4
Tafazolli, R.	University of Surrey	United Kingdom	3
Vasilakos, A. V.	Lulea University of Technology	Sweden	3
Wang, H.	GoPerception Laboratory	United States	3
Ksentini, A.	EURECOM	France	3
Koumaras, H.	National Centre for Scientific Research-Demokritos	Greece	3
Liberal, F.	University of the Basque Country	Spain	3
Kafetzakis, E.	ORION Innovations	Greece	3
Li, D.	South China Univ Technol	China	3
Flinck, H.	Nokia	Finland	3
Giannoulakis, I.	National Centre for Scientific Research-Demokritos	Greece	3
Imran, M. A.	University of Surrey	United Kingdom	3

Source: Authors

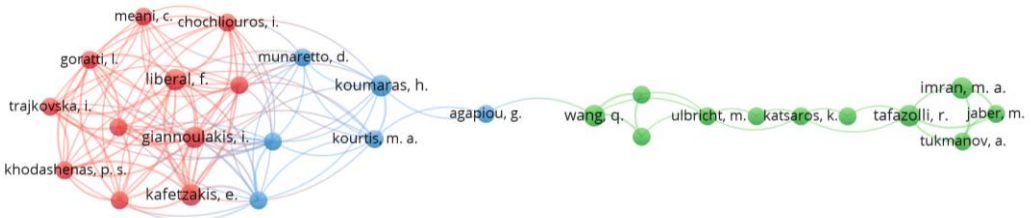

Figure 7. Network Visualization of co-authorship (VOSViewer ©).
Source: Authors

Journals

Table 9 shows the top 20 source journals for the tripod theme (Firm Network, Industry 4.0 and 5G Technology). IEEE Access, occupied the top position and published 176 articles (13,3%), followed by IEEE Transaction on Broadcasting (88 articles) and Mobile Networks and Applications (35 articles).

Table 9. The 20 source journals for the tripod research.

Journal	Occurrence	Percentage
IEEE Access	176	13,3%
IEEE Transactions on Broadcasting	88	6,7%
Mobile Networks and Applications	35	2,6%
International Journal of Advanced Manufacturing Technology	33	2,5%
IEEE Journal on Selected Areas in Communications	31	2,3%
Sustainability (Switzerland)	26	2,0%
At-Automatisierungstechnik	26	2,0%
Transactions on Emerging Telecommunications Technologies	23	1,7%
Future Internet	22	1,7%
IEEE Communications Surveys and Tutorials	22	1,7%
IEEE Wireless Communications	21	1,6%
Journal of Lightwave Technology	19	1,4%
Ad Hoc Networks	19	1,4%
Computer Communications	18	1,4%
Wireless Personal Communications	16	1,2%
Future Generation Computer Systems	13	1,0%
Computer Standards and Interfaces	13	1,0%
International Journal of Production Research	12	0,9%
Physical Communication	12	0,9%
International Journal of Communication Systems	12	0,9%

Source: Authors

Institution and country

Table 10 presents the contribution of Institutions and country from the 20 more productive authors and co-authors on tripod theme search. Note the majority (14) are from Europe and 4 from China indicating the joint work (academic and technology firms) to develop the new technologies as 5G where the main manufactory companies are from Sweden (Ericsson), Finland (Nokia) and China (Huawei).

Table 10. The 20 more active institutions x country.

Institution	Country	Count of key	Percentage
University of the Basque Country (UPV/EHU)	Spain	19	1,4%
Centre Tecnológic de Telecomunicacions de Catalunya	Spain	18	1,4%
VTT Technical Research Centre of Finland	Finland	15	1,1%
Ericsson	Italy	15	1,1%
University of Surrey	United Kingdom	14	1,1%
Aalto University	Finland	13	1,0%
Tsinghua University	China	12	0,9%
National Cheng Kung University	Taiwan	12	0,9%
University of the West of Scotland	United Kingdom	11	0,8%
National Centre for Scientific Research-Demokritos	Greece	11	0,8%
Orange	Romania	10	0,8%
South China Univ Technol	China	9	0,7%
China Telecom Co.	China	9	0,7%

Nokia	Germany	9	0,7%
Beihang University	China	9	0,7%
Huawei Technologies	Germany	9	0,7%
University of Cambridge	United Kingdom	8	0,6%
University Federico II of Naples	Italy	8	0,6%
Univ Miskolc	Hungary	8	0,6%
King Saud University	Saudi Arabia	8	0,6%

Source: Authors

Qualitative research

To support a gap analysis in the keyword codes generated by the bibliometric research, a script of the interview was conducted following the guidelines present in Froemming (2001) and Flanagan (1954) regarding the Critical Incident Technique. The interview script involves semi-structured questions aimed at seeking participants" conceptions and opinions (**Table 11**).

Table 11. Applied questions to experts during interviews.

Topic	Questions
Industry 4.0 and 5G in the supply chain	How do you assess the potential for companies to be impacted by Industry 4.0 and 5G technologies so that their position in the supply chain (as a supplier, system integrator, industry, distributor or consumer) is positively affected? or negatively? What factors relate to this impact? What consequences of these factors?
Partnerships	How do you assess the potential for companies to be impacted by Industry 4.0 and 5G technologies with partnership opportunities (inside or outside the industry)? What factors relate to this impact? What consequences of these factors?
5G as Industry 4.0 enabler	What is the potential of 5G technology to enable Industry 4.0 requirements?
Competition	Based on your industry experience, what impact on the competitive relationship (relationships, opportunities, and threats) considering Industry 4.0 and what can 5G technology provide?

Source: Authors

We applied interviews to 10 subject matter experts in Brazil, with total of 274 minutes recorded. The interviews were transcript in Portuguese and imported in NVivo to find the 20 more frequent words in order to find gaps and insights by mapping to articles search database. The **Table 12** shows the 20 more frequent words translated to English.

Table 12. 20 Most frequent words in qualitative research (transcript interviews into NVivo©).

#	Word	Occurrence
1	industry	185
2	enterprises	155
3	technology	110
4	information	77
5	people	45
6	impact	44
7	capacity	42
8	market	37
9	business	30

10	product	53
11	partnerships	48
12	relationship	27
13	factors	26
14	process	26
15	potential	25
16	telecom	22
17	competition	17
18	development	17
19	security	17
20	velocity	17

Source: Authors

4. RESULTS AND DISCUSSION

Research

The bibliometric research (list of authors, co-authors and institutions) shows the presence of technology companies in the joint work with the academic space, which indicates the efforts in research and development of companies involved in the development of the ecosystem of Industry 4.0 and Networks 5G. Some of the most frequent words in the database of all articles are not present in the most frequent word sources (keywords used in WOS and Scopus research, most frequent co-occurring words and most frequent words in qualitative research), with more attention to “management” and “control” which indicates, even not present in the abstracts and titles, the sub-theme management and control of the new technology (Industry 4.0, 5G Networks) should be the target of specific studies.

For interviews with experts on the subject, the 5th most frequent word “people” is noted, which indicates the concern with the impact that new technologies will have on people”s lives and should be the subject of furthe studies.

Some of the most frequent words in the database of all articles are not present in the most frequent word sources (keywords used in WOS and Scopus research, most frequent co-occurring words and most frequent words in qualitative research), with more attention to “management” and “control” which indicates, even if not present in the abstracts and titles, the sub-theme management and control of the new technology (Industry 4.0, 5G Networks) should be the target of specific studies.

For interviews with experts on the subject, the 5th most frequent word “people” is noted, which indicates the concern with the impact that new technologies will have on people”s lives and should be the subject of further studies.

The answers (interview transcripts) to the questions as perceived by these experts were coded and categorized (Strass e Corbin, 1998, 2008) regarding steps presented by Kent Lofgren (2019) to identify themes and explore questions and hypotheses associated with the topic under study. Based on these coded data, a total of 16 hypotheses were classified in 5 different categories: Partnership (4), Competition (4), Products and Services (3), Security (3) and People (2).

The hypotheses classified as Security and People were discarded for not establishing a causal relationship on the tripod theme (Firm Network, Industry 4.0 and 5G Technology) that would allow the formulation of a relationship model.

Conceptual reference model

The hypotheses are presented in **Table 13**, with the identification of their classification according to the codified perceptions regarding the themes explored in the literature review, excluding the hypotheses related to Security and People for not establishing a causal relationship on the tripod research theme that would contribute to a relationship model development.

Table 13. Hypotheses associated with the Conceptual Research Reference Model.

Hypotheses	Cluster	Code	Questions
H1	Partnership	HPa1	5G and Industry 4.0 technologies positively influence the structuring of new partnerships
H2	Product and Services	HPr2	5G and Industry 4.0 technology positively influences greater competition in the manufacturing industry as an enabler of customizations
H3	Competition	HCo1	New partnerships positively influence greater competition against small and innovative new companies
H4	Partnership	HPa3	New partnerships positively influence the expansion of the ecosystem
H5	Competition	HCo2	Greater competition with companies from other sectors as entrants positively influences an Expanded Ecosystem

Source: Authors

From the graphical representation (**Figure 8**) of the hypotheses and the relationship between actors, a Conceptual Research Reference Model was developed that inductively reflects (Strauss and Corbin, 1998) a conceptual model of balanced competitive expansion. Taking the managerial implications of networking on competitiveness, the working closely with vendors on one hand and clients on the other is crucial for long-term success and for being competitive (HUSSAIN Z. et al., 2016) while the exploitative inventions improve firms´ development of breakthrough innovations (COHEN, S.K. et al, 2016). That is, the greater competition caused by new entrants and new services is balanced with the expansion of the market ("new money") and the partnerships settlement between large corporations and smaller companies focused on supporting them in new technologies.

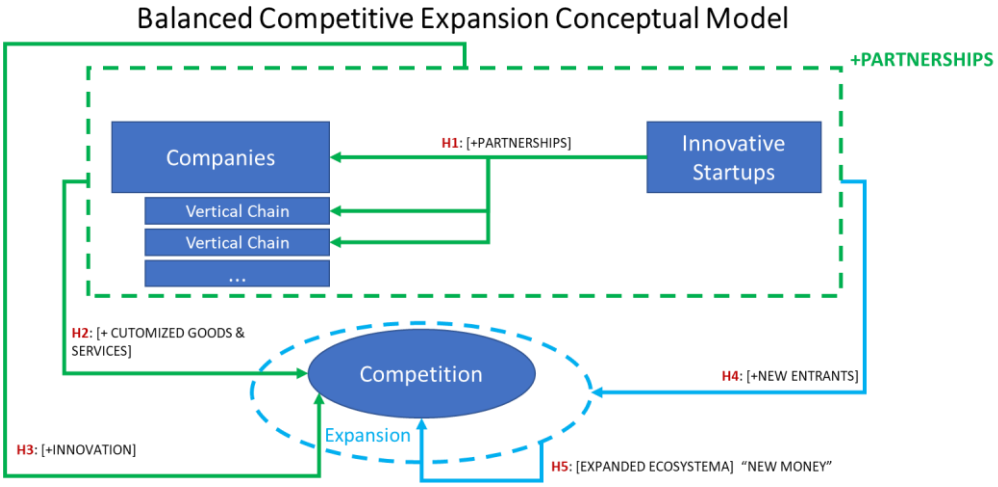

Figure 8. Conceptual Model.
Source: Authors

5. CONCLUSION

The researched theme based on the tripod "Firm Network", "Industry 4.0" and "5G Technology" obtained relevance in the last years (76% from selected articles were published since 2017).

By the bibliometric research (list of authors, co-authors and institutions) we note a presence of technology firms in jointly work with academic space, what indicates the efforts in research and development from the companies involved in the Industry 4.0 and 5G networks´ ecosystem development.

We note some of the more frequent words from all-articles database is not present in the sources of more frequent words (keywords used in the WOS and Scopus search, most co-occurring frequent words and more frequent words in qualitative research), with more attention to "managing" and "control" that indicates even not present in the abstracts and titles, the sub-theme of management and control of the new technology (Industry 4.0, 5G Networks) should be target of specific studies.

For strategic and production, the combination of bibliometric and qualitative researches brings opportunity to find relationships and gaps between the main topics addressed by the academic environment and the immediate perceptions from executives regarding market and technology trends.

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