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Implementing Industry 4.0: Exploring the literature in a systematic way using text mining

(Full Paper)

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ABSTRACT

The increasing popularity of digitisation practices and methods by scholars and practitioners alike has been paving the way for industrial transformation. Industry 4.0 has become an accepted trend across various industries, yet despite the increasing number of articles on this topic the complexities of implementation at the firm level remains largely vague and undefined. Therefore, the research presents a review of the social, operational and strategic aspects following the full-text mining of 116 selected articles. The study reveals that digital transformation requires stakeholders and investors to consider implementation through a multi-level and multidisciplinary lens. On this basis the study identifies the social, operational and strategic gaps within the literature and provides recommendations for future studies on implementation.

Keywords: Industry 4.0, IIoT, CPPS, Implementation, Systematic review

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INTRODUCTION

Academic research on Industry 4.0 (I 4.0) has been increasing in popularity among scholars in the last decade. However, due to the multifaceted nature of Industry 4.0 and the fact that it is very much a novel and ongoing process, academic contributions mainly focus on the technical aspects (Primarily engineering and computer science) as opposed to the managerial or business aspects of I 4.0. The asymmetrical approach of the academic community to I 4.0 necessitates further contributions from the management science academic community (Liao et al, 2017). Schneider (2018) divides the academic approach of scholars of I 4.0 into two main groups, namely: researchers aiming to clarify the impact of I 4.0 on specific markets by quantification and subsequent evaluation of performance metrics, termed "distinct industry 4.0 research". In contrast, the second category, termed "Industry 4.0 as a promising context", aims to study established research fields such as supply chain management (SCM) and entrepreneurship within the context of I4.0 by further investigating the implications of implementation. Liboni et al (2019) support a similar division of academic studies by classifying priory research into *"Industry 4.0 as the central emphasis"* and "*Industry 4.0 as support to other discussions or technical aspects"*.

The main distinguishing factor of I 4.0 in comparison to previous trends is the utilization of cyber physical systems (CPS) or cyber physical production systems (CPPS) within the context of manufacturing, enhanced by the industrial internet of things (IIoT) to interlink the various elements of production into a reliable and continuous loop of information sharing. It is worth mentioning, however, that the term "Industry 4.0" has been interchangeably used with "Industrial internet of things" or IIoT in the extant literature (Müller, Kiel, and Voigt, 2018). The surge of scholarly publications on this topic has been steadily increasing but the progress across academic disciplines remains uneven, Schneider (2018). The division of academic work on "Industry 4.0" can be further clarified by subdividing extant publications by academic category or subject area. As illustrated by table 1, dividing prior research papers from Scopus (5,599 results) and Web of Science (3,304 results) databases without setting any search limitations provides a holistic view of the subject areas that are prioritized by the academic community. As of July 2019, both databases reveal a higher number of published papers in the engineering and computer science fields, with the social science and management fields lagging behind in terms of published content. Furthermore, the increasing volume of research papers published within the field of I 4.0 focuses in depth within a specific sector or technology, while the underlying concepts of I 4.0 remain isolated within and across many research fields. This is particularly true within the social sciences and particularly within the field of business and management, as many topics remain vague, ill defined, and dependent on the interpretation of the scholars, necessitating a holistic review of the literature and subsequent identification of the most significant research gaps that need to be addressed. The current review aims to add to the I 4.0 body of knowledge by examining only implementation-related papers and providing a quantitative analysis of the selected papers through data mining. In comparison precious works only examine I 4.0 by examining emerging management trends (Schneider, 2018) or only included the abstracts of the papers into the TDM (Galati and Bigliardi, 2019).

The primary objective of the present review of the literature is (i) to provide a holistic view of the current trends in I 4.0 from a managerial implementation lens to identify the overarching themes and (ii) to conduct a systematic literature review within each theme to illustrate the academic progress within as well as across the themes. The priority of the present study is to identify, select and ultimately analyse papers that exemplifying real-life use cases and pilot programs of I 4.0 initiatives across a variety of industrial sectors and from an academic perspective (I.e. Case study, surveys and interviews) as opposed to theoretical and conceptual papers that have limited relation to implementation.

METHODOLOGY

The initial stage of the methodology has been designed to cluster the main themes into groups according to the frequency and co-occurrence of keywords. The first stage is further subdivided into: data collection, pre-processing and the text and data mining (TDM) stage. This was followed by the systematic literature review of each cluster to address the second research objective. Text mining and natural language processing (NLP) specifically is used increasingly by academics to highlight the main themes from a large set of structured and unstructured textual data apparent in developing fields such as I 4.0, therefore the TDM method has been prioritized for the current systematic literature reviews. Moreover, due to ease of access only the summary or abstract of journal articles was included in prior research into I 4.0 using similar methodology. Consequently, this research aims to go beyond the data included in the abstract and analyse the full-text files to provide a more comprehensive representation of extant topics.

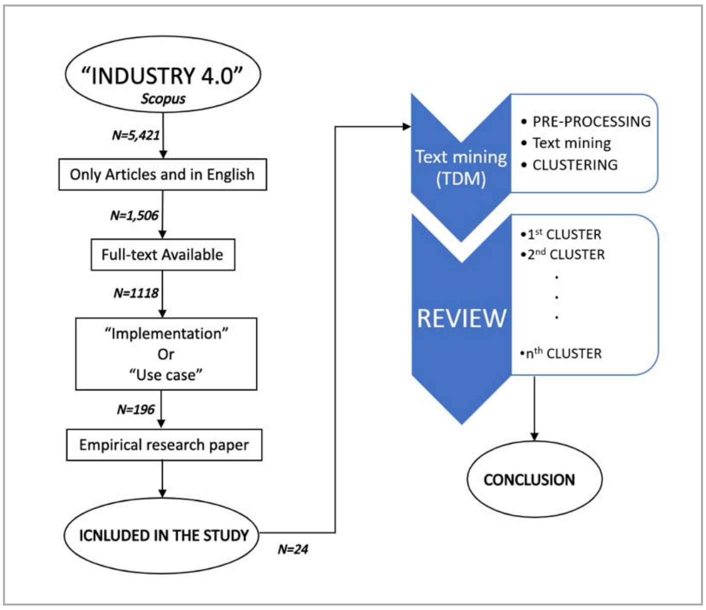

Figure 1: Methodology Flow Chart

Prior to the analysis of the selected documents using text and data mining (TDM), the pool of papers is subjected to a set of selection criteria. To minimize subjective selection, the papers are narrowed down to the final corpus through three progressive stages of data collection, pre-processing and the text mining operations, and eventually the clustering of the results into themes as shown in figure 1.

Data collection

The current research employs content analysis of a set of academic papers from the corpus database prior to the systematic review of individual themes. To capture the full spectrum of data contained in academic papers relating to the implementation of I 4.0 all the articles with the keyword "Industry 4.0" mentioned in the title, keywords or abstracts of the paper have been selected, totalling 5421 articles as of July 2019. In order to further narrow down the search, only journal articles written in the English language have been selected, providing 1506 results. Consequently, a secondary search has been conducted to select the papers that include the keyword "Implementation" in the title, abstract or keywords (n=544) and those that are available as full-text files (n=196) have been selected for the final screening stage. Furthermore, 116 papers rated three had full compliance with the inclusion criteria and focus on prior empirical studies. In contrast, papers rated one or two were excluded due to their technical focus or lack of relation to implementation.

Pre-processing

The pre-processing stage aims to clean the data presented in the articles to reveal the relevant textual data for the next stage of the TDM. For the purposes of this research the figures and images as well as the data contained within brackets "()" and braces "{}" have been removed as this presents irrelevant or duplicate data. Furthermore, in order to consider similar words such as "Industry 4.0" and "Industrie 4.0" under the same meaning, a Lemmatization method has been use

Text and data mining: After the pre-processing stage the set of articles is uploaded into QDA miner add-on software called Wordstat for full text analysis. In order to clarify the existing clusters within the corpus, the keywords illustrated in the frequency analysis (limited to 100 results) shown in the example below is reviewed to remove partial word segments (I.e. AGRI) and separate those from acronyms such as IoT and OPC. This has been accomplished by examining the key word-in-context for every term which shows the list of case segments (article chapters) from which the term has been extracted. Furthermore, the term frequency-inverse document frequency (TF*IDF) of every keyword is reviewed to separate keywords with high frequency yet low case occurrence. The clustering of the cases is accomplished through initial thematic clustering of the TDM results and correlation of keywords with the original articles.

Literature review: From the pool of 118 articles included in the TDM, 24 papers are selected for the full text review to capture the overall theme. Although adding more papers to the qualitative review would add to the depth of the research, the number or content of the main themes would not change. For the purpose of this research particular attention has been paid to following a coherent article structure, choosing the right balance between breadth and depth, and focusing on concepts (concept-centric) by thematically structuring the review section as opposed to a chronological or alphabetical structure of the extant publications (Fisch and Block, 2018).

RESULT

The following section presents the results of the text mining operation, including a review of the frequency analysis, a dendrogram and link analysis. The TF*IDF represents the importance of a word within the context of the larger corpus. This is of particular importance as I 4.0 remains a novel topic and certain words may be highly frequent in one article but not representative of emerging themes. As shown in table 1, the term “CLOUD” has a frequency of 1236 and the term is used in 68 articles (56.67%) included in the corpus, corresponding to TF*IDF of 304.9. In comparison, the term “JOINT” is mentioned 77 times in 42 cases, representing a TF*IDF of 35.1. The following table shows the 62 keyword results with the highest TF*IDF. The results indicate a focus on the main technologies of I 4.0 such as Cloud, IoT, CPS and robots, representing the enabling factors of I 4.0, with TF*IDF of 304.9, 179.7, 152.9, and 311.7 respectively. Nonetheless, the high frequency and case occurrence of other keywords such as Lean and assembly tends to reveal the importance of comprehending the current state of the industry. In other words, the frequency analysis illustrates that there is a link between the current state of the industry and the requirements of I 4.0 transformation.

The inter thematic link is further exemplified by the link analysis of the social related terms and the apparent connection of the terms “Experience”, “Consumer”, and “Customer” with operational terms such as IoT and Computing. Furthermore, excluding isolated terms such as “EU”, which only has a case occurrence of 32.50%, reveals the connection of the remaining keywords. In addition to the technology related cluster, which includes the above-mentioned terms as well as “sensor”, “Maintenance”, and “Equipment” there is a cluster related to the operational aspects of smart manufacturing, which seems to be more common than other themes, as shown in figure 4. Nonetheless, based on figure 2, the inclusion of strategy related terms such as “Lean”, “Digitization” and “Interaction” illustrates a second theme related to the strategic management of firms. Lastly, according to figure 3 the occurrence of social related terms such as “Consumer”, “Customer”, “Experience”, “Engineer”, and “Competitiveness” reveals a third cluster related to the social implications of I 4.0 implementation as both the high frequency and case occurrence implies the increasing importance of social topics in the extant literature within the corpus. Moreover, figure 6 illustrates the strong link of social terms with operational themes (e.g. Assembly & Maintenance) as well as strategic themes (e.g. Lean).

Table 1: Keyword Statistics

Keyword	FREQUENCY	% CASES	TF * IDF
ROBOT	1114	52.50%	311.7
ASSEMBLY	797	40.83%	310.0
CLOUD	1236	56.67%	304.9
LEAN	549	40.83%	213.6
EQUIPMENT	688	53.33%	187.8
ARTIFICIAL	386	34.17%	180.0
IOT	856	61.67%	179.7
FACTORY	1341	76.67%	154.7
DIGITIZATION	286	29.17%	153.0
CPS	508	50.00%	152.9
CONSUMERS	552	56.67%	136.2
SERVERS	237	30.00%	123.9
MODULE	276	35.83%	123.0
SIMULATION	421	51.67%	120.7
MANUF	301	40.00%	119.8
CUSTOMER	368	47.50%	119.0
HTTPS	633	66.67%	111.5

Keyword	FREQUENCY	% CASES	TF * IDF
PRODUCTIVITY	274	53.33%	74.8
DETECTION	134	28.33%	73.4
INTERACTION	276	55.00%	71.7
ADAPTATION	131	28.33%	71.7
FAILURE	189	42.50%	70.2
COMPETITIVENESS	129	30.00%	67.5
MANUFACTURE	155	37.50%	66.0
REDUCTION	187	45.00%	64.8
ROBOTICS	154	40.83%	59.9
CONNECTIVITY	109	28.33%	59.7
ADAPTIVE	168	44.17%	59.6
ELECTRICAL	140	37.50%	59.6
ENGINEERING	1104	88.33%	59.5
DEPLOYMENT	115	30.83%	58.8
EU	120	32.50%	58.6
STORAGE	168	45.83%	56.9
MECHANICAL	234	57.50%	56.2

SENSOR	353	49.17%	108.8	PROTOCOL	199	35.00%	54.3
MAINTENANCE	652	68.33%	107.8	ENGINEER	199	35.00%	54.4
SCHEDULE	312	46.67%	103.3	AUTOMATIC	116	37.50%	49.4
PLANT	281	43.33%	102.1	CONTROLLER	92	29.17%	49.2
MANUAL	254	40.00%	101.1	DEPLOY	101	33.33%	48.2
REVOLUTION	379	54.17%	100.9	REMOTE	92	30.00%	48.1
COMPUTING	535	65.00%	100.1	TECH	217	60.83%	46.8
AUTONOMOUS	196	33.33%	93.5	MATION	100	34.17%	46.6
CYBER	740	75.00%	92.5	EQUIP	83	34.17%	38.7
EXPERIENCE	362	55.83%	91.6	ENVIRON	72	29.17%	38.5
SAFETY	254	45.00%	91.6	EXPECTATION	73	30.83%	37.3
CONSUMPTION	176	31.67%	87.9	JOINT	77	35.00%	35.1
MULTI	293	55.00%	76.1	REVISE	39	30.83%	19.9

It is important to note, however, that most terms relate to more than one theme. As illustrated in figure 5, “Lean” may be related to the lean management practices at the management level as well as lean practices at the factory floor. The multilevel connection of operational practices is also illustrated in the dendrogram (Figure 5) as the operational, strategic (i.e. OEE) and social terms (i.e. HRC, Safety) are interlinked. Similarly, the term “Connectivity” may refer to the connectivity of machines as the link to the term “Electrical” in the dendrogram reveals, or it may refer to the connectivity of consumers or the workforce; however, the latter may be more related to the term “Interaction”, as more links are observable.

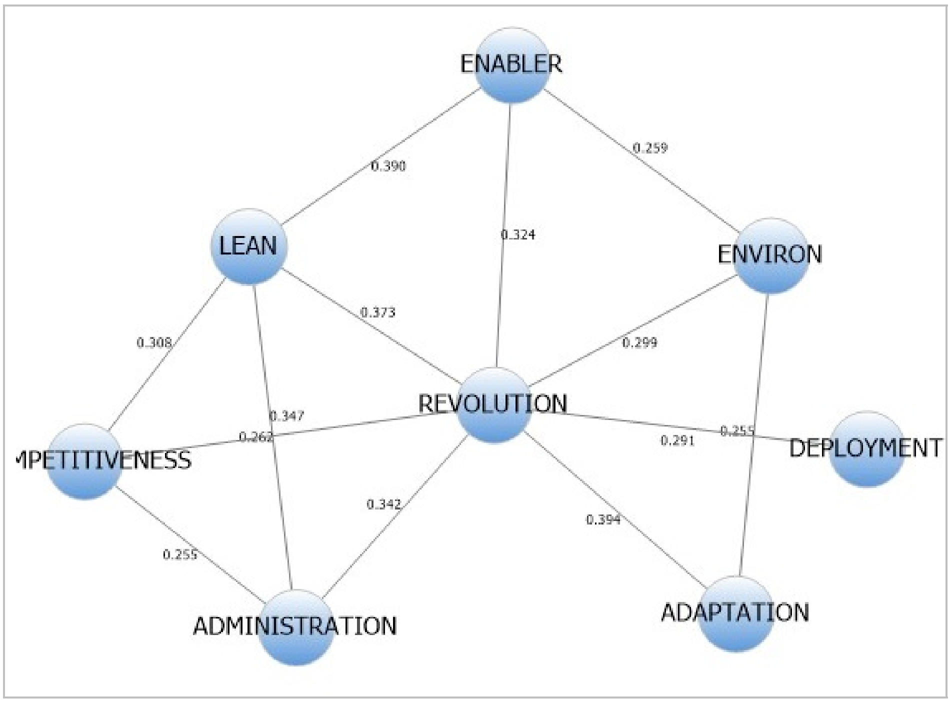

Figure 2: Strategic Link Analysis

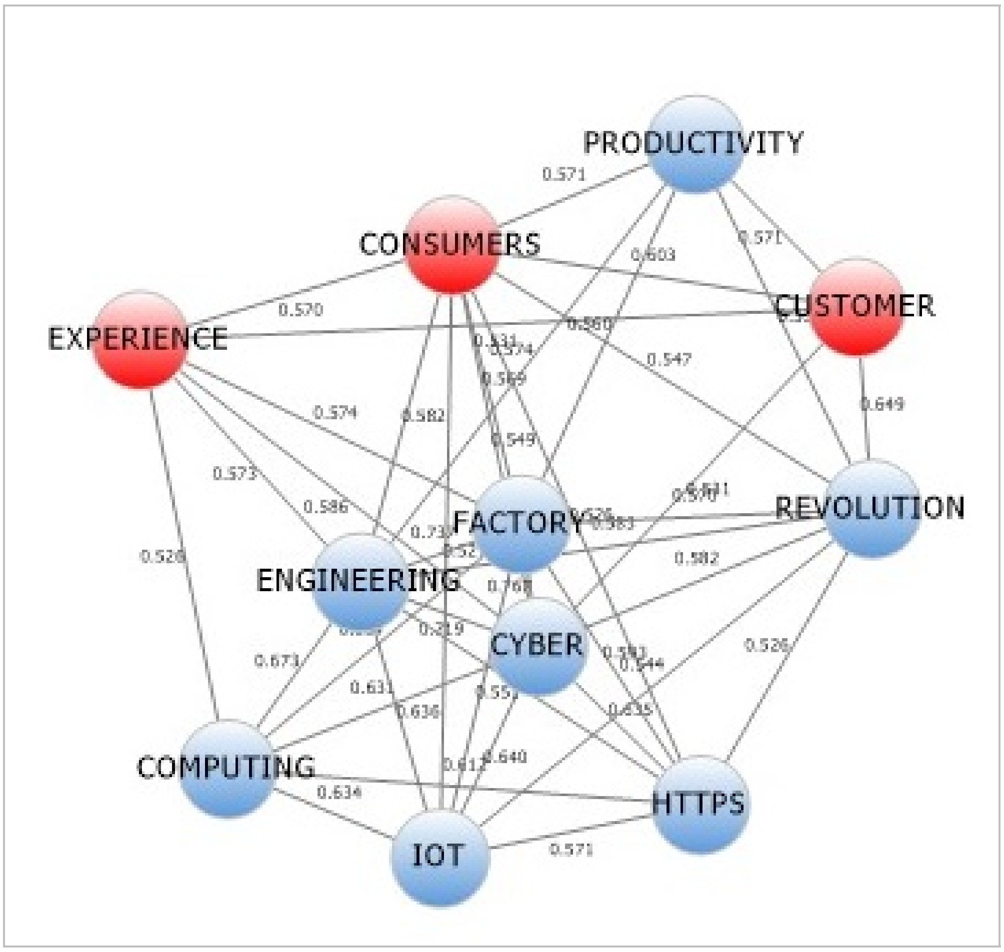

Figure 3: Social Link Analysis

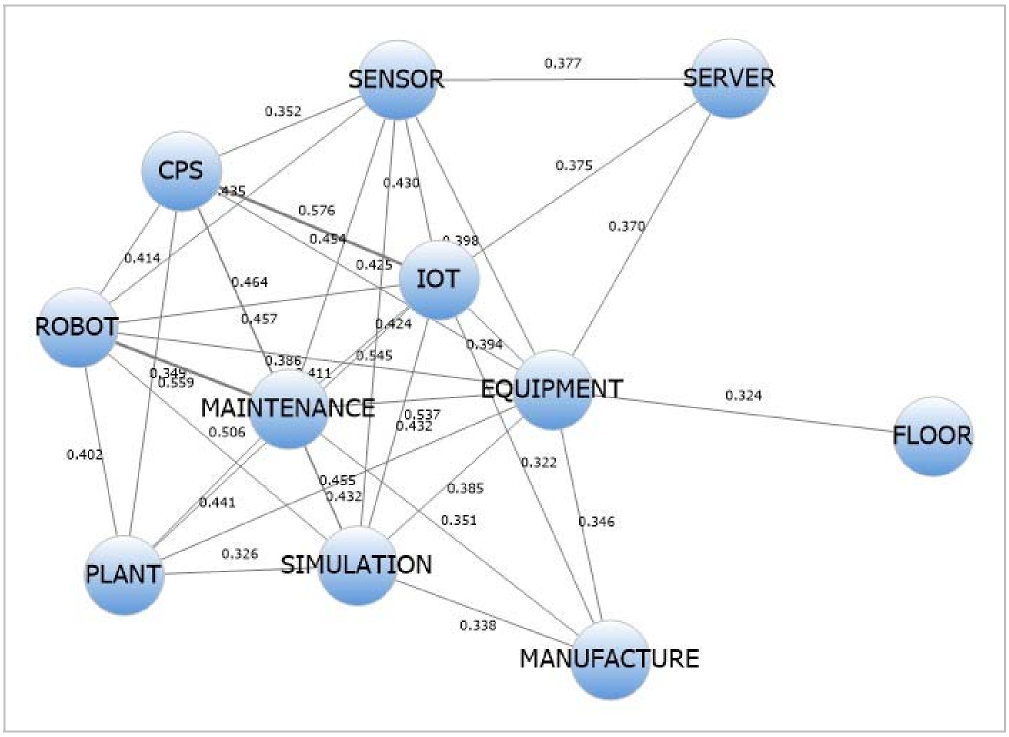

Figure 4: Operational Link Analysis

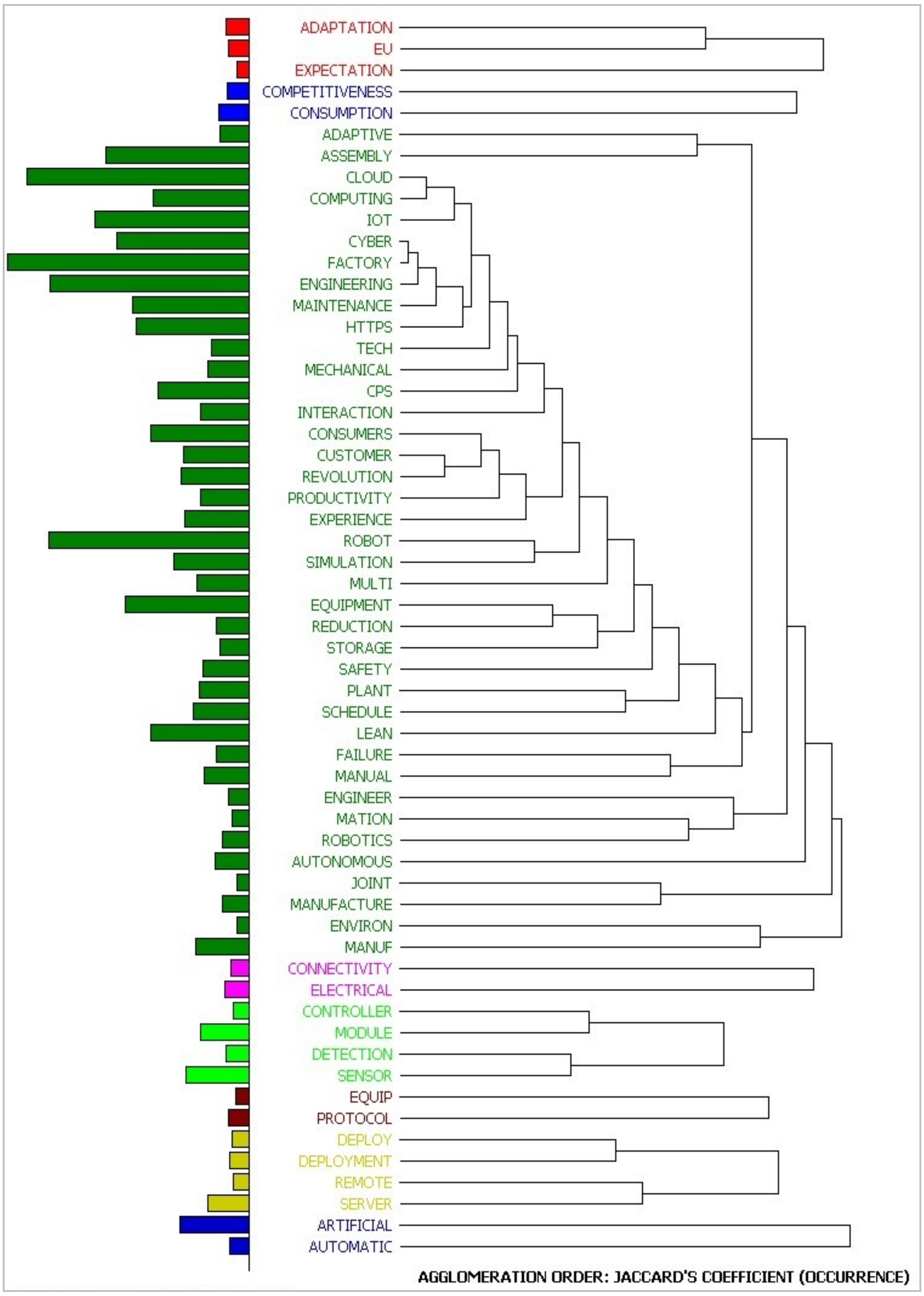

Figure 5: Dendrogram

In general, the most prevalent them in the present study is the operational theme, which represents the technologies and methods employed at the factory level, followed by strategic management and social implications. Furthermore, given the formation of clusters apparent in the frequency list and the link analysis and the interconnectivity of the underlying themes, it is necessary to review each theme in more detail by qualitative analysis of each case to determine the state of the literature and reveal gaps.

The final stage of the text mining relates the keyword clusters back to the cases (Articles) from which they predominantly originate. Due to limitations of space, an example of the three clusters and the corresponding cases is shown in table 2. In total, out of 116 cases included in the study, 48 are related to operational aspects, 50 are related to management strategy, and 18 are related to the social implications of I 4.0 implementation.

Table 2: Case clustering

	TERM EXAMPLE	CASE EXAMPLE
Social Cluster	***"Competitiveness"*** ***"Experience"*** ***"Safety"*** ***"Interaction"*** ***"Customer"*** ***"Consumer"***	Gorecky (2017), Introduction and establishment of virtual training in the factory of the future Dukalski et al (2017), Portable Rapid Visual Workflow Simulation Tool for Human Robot Coproduction Li et al (2018), Research on Dynamic Facility Layout Problem of Manufacturing Unit Considering Human Factors Antosz (2018), Maintenance - Identification and analysis of the competency gap
Operational Cluster	***"Robot"*** ***"Assembly"*** ***"Cloud"*** ***"Equipment"*** ***"CPS"*** ***"IoT"***	Larrinaga et al (2019), A Big Data implementation of the MANTIS reference architecture for predictive maintenance Lee et al (2019), A blockchain enabled Cyber-Physical System architecture for Industry 4.0 manufacturing systems Lee et al (2015), A Cyber-Physical Systems architecture for Industry 4.0-based manufacturing systems Yue et al (2015), Cloud-assisted industrial cyber-physical systems: An insight Yoon et al (2019), Smart Factory Information Service Bus (SIBUS) for manufacturing application: requirement, architecture and implementation Wan et al (2017), A Manufacturing Big Data Solution for Active Preventive Maintenance
Management Cluster	***"Lean"*** ***"Digitization"*** ***"Revolution"*** ***"Productivity"***	Müller (2019), Business model innovation in small- and medium-sized enterprises: Strategies for industry 4.0 providers and users Ante et al (2018), Developing a key performance indicators tree for lean and smart production systems Bär et al (2018), Considering Industry 4.0 aspects in the supply chain for an SME Prause (2015), Sustainable business models and structures for industry 4.0 Mueller (2017), Challenges and Requirements for the Application of Industry 4.0: A Special Insight with the Usage of Cyber-Physical System

DISCUSSION

As briefly examined in section 1.1, the fourth industrial revolution and I 4.0 specifically, is an ongoing paradigm that is taking shape and that is gradually evolving depending on the decision making of involved stakeholders at multiple levels and stages. Although industrial strategies at the national and regional level constitute an underlying policy and legal framework for I 4.0 adaptation, the main drivers of change and sources of innovation remain at the factory and individual levels. On the other hand, Morrar, Arman and Mousa (2017) look at the global effects of I 4.0 from a social innovation perspective and argue that the global society should benefit from the forthcoming industrial revolution as consumers and producers are becoming more connected. This multifaceted nature of I 4.0 implementation potentially maximises the benefit to early adapters, but as a multidisciplinary approach is required, research can be slowed down by isolated studies that may not initially reveal a link. Therefore, the following section provides a thematic map of recent developments within the academic literature on I 4.0 adaptation based on the results of the TDM and qualitative analysis of the selected articles.

Multi-layered Approach to Implementation

Scholarly articles elaborating the regional complexities of I 4.0 are also scarce but compared to the global level (Macro-level), more authors are involved. Santos et al (2017) study the European strategy for I 4.0 implementation. The authors state that implementation across multiple nations within a region requires the collaboration of stakeholders in the form of forums such as the European technology platforms (ETPs), the European factories of the future association (EFFRA) and public-private partnerships (PPP). Ciffolilli and Muscio (2018) further analyse the implications of implementation within Europe by conducting an empirical study on the investment towards I 4.0 within regions of member counties. The study finds that in contrast to EU policy on I 4.0 implementation (Santos et al, 2017) the flow of investments is only directed towards "I 4.0 hubs", resulting in a lack of funding and modernization in many regions, impeding the regional implementation of I 4.0 initiatives. Moreover, Castelo-Branco, Cruz-Jesus, and Oliveira (2019) provide a study on the implementation strategies and methods of the European manufacturing sector and reiterate that regions show large disparities in the level if implementation. Nonetheless, the authors argue that regions that are not considered as hubs can be involved and connected through the development of a unified digital infrastructure, such as the single digital market (SDM) and the promotion of analytical capabilities to deal with and interpret the volume of data generated. Table 3 illustrates examples of the main articles associated with the national level implementation as well as the findings.

Due to the vast amount of resources required for change, the social and strategic implications of adaptation have not been comprehensively studied within the context of developing or underdeveloped nations. Schneider (2018) states that as opposed to industrial nations, developing nations are likely to experience the "brownfield scenario", in which existing processes and infrastructure cannot be replaced, and investment is justified by gradual upgrades of current technology.

Table 3: Regional development

Author(s)	Country	Findings / Gaps
Zhou, Liu and Zhou, 2015; Müller, Kiel and Voigt, 2018; Wilkesmann, 2016	Germany	I 4.0 will increase productivity by 30%. Social, operational and strategic opportunities drive the implementation of I 4.0 but risks of competition and future viability impede implementation. Implementation strategy strongly depends on the company size, location and culture. More international studies are required to facilitate optimization and standardization.
Sung, 2018; Park, 2016	Korea	Lack of adequate skill set, reluctance of stakeholders to change, loss of low and medium skilled jobs due to automation. Standardization of core technologies is needed. Further collaboration between government and private sector is recommended.
Li, 2018; Zhou, Zhou and Liu, 2015	China	More work is needed on the managerial implications at the firm level and with regard to inter and intra company collaborative scientific activities. The discrepancy between societal and industrial impact needs to be further studied.

Thematic Development

In order to further analyse the requirements and prerequisites of I 4.0 implementation, it is necessary to subdivide the various implementation approaches cited within the relevant literature to clarify the main themes and constituent parts. The division of academic studies provided by Schneider (2018) as elaborated in the previous section is further subdivided into three subcategories: (a) technical elements of operation (e.g. cybersecurity, new product development), which is the focus of engineers across multiple research fields, (b) novel strategic management approaches to traditional business operations (e.g. supply chain management, marketing and business model innovation), and (c) the social aspects (e.g. human resource management, training, mental and physical safety), which involves workers, managers, customers and consumers (Müller, Kiel and Voigt, 2018). This classification falls in line with the distinctions of Galati and Bigliardi (2019) and Stremersch and Van Dyck (2009), but the classification of the latter authors is further subdivided into six and four classifications respectively. Zhou, Liu and Zhou (2015) provide an alternative factory-level strategy for implementation, which is more inclined to the German implementation strategy. The strategic plan can be summarized as building a network, researching two major themes, realization of three integrations and achieving eight planning objectives. The plan culminates in building a network of connected devices and people in the form of cyber physical systems (CPS) to facilitate and elevate the capabilities of computing, communicating, precision control, coordination, and autonomy within the manufacturing environment. The two main themes prioritized for research include: the "Smart factory", which focuses on the underlying systems and processes within and across network connected production facilities, and "intelligent production", which takes into account the human-computer interactions, the management and logistics and the required physical and virtual technologies.

Ultimately the implementation strategy initially proposed by Conti et al (2017) and further elaborated by Zhou, Liu and Zhou (2015) aims to achieve the following eight objectives: (1) the standardization of systems and the conception of a reference architecture, (2) efficient management, (3) the establishment of a comprehensive industrial broadband infrastructure, (4) safety and security, (5) the organization of design work, (6) staff training and continuing professional development, (7) establishing a regulatory framework, and (8) improving the efficiency of resource use. Establishing a sustainable digital strategy or plan at the firm level exposes hidden and unknown barriers to implementation and clarifies the path for digitalization.

Strategic implementation

The strategic management of business operations at various management levels (i.e top management, HRM, Operations management, SCM, CRM etc.) remains at the core of the digital transformation of a company and strongly influences the operational and social implementation of I 4.0 practices (Schneider, 2018). The company's business model (BM) defines and clarifies the plan and objectives for internal stakeholders as well as potential investors. Nonetheless, increasing competition, the changing global markets (Globalization) and increasing market volatility necessitates the continuous change of BM's and the introduction of a digital transformation strategy by many firms (Lasi et al, 2014). With regard to the initial stages of the business model shift towards a digital strategy, a study on the business model innovation of SME's examines a set of 43 expert interviews with German manufacturing sectors such as automotive suppliers, electrical, mechanical and plant engineering, Müller (2019). The author acknowledges the limited scholarly focus on the management aspects (particularly business models) of implementation as opposed to the economic and technical aspects of implementation, reinforcing the findings of other authors such as Arnold et al (2016), who examine the impact of IoT on business model innovation across multiple sectors, and Loebbecke and Picot (2015), who examine business model transformation as a result of big data analysis (BDA). According to Müller (2019), "technologically triggered business model innovation" constitutes the backbone of digital transformation. Beyond the prior literature on business model innovation, the project management aspects are of paramount importance to the successful implementation of I 4.0 for a given firm. Traditional project management practices aim to introduce consistency, flexibility and efficiency at the enterprise level or the underlying departments and consist of process description, work breakdown structure, life cycles, roles and responsibilities and templates in addition to total quality management (TQM) as elaborated by the project management institute (PMI) according to ISO 9001 standards (Martínez-Costa et al, 2009). Jovanović et al (2015) elaborate on the difference between lean manufacturing and agile manufacturing and argue that, as opposed to traditional project management approaches, the agile management approach involves a creative and innovative approach due to unclear project requirements and an iterative project plan.

Operational implementation

An increasing number of scholars are studying the operational aspects of I 4.0 and proponents of operational change argue that there is a direct correlation between the expected load balancing such as production optimization (Ding, Jiang and Zheng, 2017; Weinert, Chiotellis, and Seliger, 2011) and waste reduction and therefore a reduction in greenhouse gas emission (Peukert et al, 2015). Various I 4.0 technology providers have presented digital platforms for I 4.0 users. Chen (2017) provides a study on the enabling technologies, including CPS, Industrial internet, Machine learning, Cloud computing, and Big data analytics. The author further examines digital platforms based on the aforementioned technologies provided by: General Electric, providing Predix edge, Predix cloud and Predix machines for data collection and BDA, Siemens, providing factory floor technologies and digital twin model software platforms, and PTC ThingWorx, providing IIoT platforms. The author agrees that digital platforms provided by technology companies in conjunction with governmental support shows the most promising potential for implementation from a I 4.0 user perspective. Alternative studies on the operational aspects of I 4.0 within the manufacturing sector examine the production planning and control. Tsai and Lu (2018) analyse a tire making factory under I 4.0 and argue that traditional cost systems are diminishing in favour of activity-based costing (ABC). At the operational level ABC uses resource drivers and activity drivers at four levels, namely, Unit-level activities (I.e. 100% inspection), batch-level activities (material handling, set-up, scheduling etc.), product-level activities (product advertising, designing etc.), and facility-level activities. The authors further state that operational activities can be managed based on the shop floor control (SFC), which, according to the authors, "parameterizes the real-time shop floor data for control" by collecting data from the Manufacturing Execution System (MES) among other sources of data.

Social implementation

The strategic and operational aspects of implementation are considered as the initial stages and the backbone for I 4.0 adaptation within the manufacturing sector, though many scholars argue for more research on the social impacts of implementation. Müller (2019) argues that employee resistance and the fear of being replaced or having inadequate digital skills in the upcoming industrial transformation significantly impedes implementation at all stages, adding that existing personnel might become obsolete. This social shift necessitates the need for "creative problem-solvers" in multiple organizational positions (Kiel, Arnold, and Voigt, 2017; Müller, Kiel and Voigt, 2018) and requires the entire workforce to evolve as the digital transformation unfolds (Sjödin et al, 2018). Other authors take an alternative stance and argue that in contrast to the traditional industrial eco-system in which the worker had to adapt to the working environment, in the era of I 4.0 social needs and habits are pushing the industrial transformation (Jovanović et al, 2015).

A quick review of the above subthemes reveals that implementation of I 4.0 is not only dependant on the industry sector or company size, but also on the various levels within a company. This can be a determining factor in the successful transformation of departments and internal sectors, such as Human resources (HR), Logistics/Supply chain, and multiple management levels. Qualitative analysis of the selected papers illustrates that previous research on this topic is primarily concentrated on what has been identifies by Schneider (2018) as a promising research avenue. Therefore, one of the main limitations is the lack of studies on evaluating this transformation. A second limitation is the lack of studies on the implication of human factors in relation to the ever-increasing trend of automation and robotization. Many companies lack a coherent management structure that is based on lean and agile manufacturing either as a result of lack of resources, small size of the company or inadequate returns. This can be further exacerbated by systematic reluctance of top management to change or on the exclusion of involved workers from the decision-making process.

CONCLUSION

Academic management scholars largely agree that the implementation of I 4.0 at the firm level requires a multidisciplinary approach. The present study has compiled recent articles on implementation and conducted a text and data mining (TDM) operation on the selected articles. The results of the TDM and subsequent qualitative analysis of the underlying themes reveals that managerial empirical studies on I 4.0 implementation at the firm level remain scarce yet are highly in demand within the academic and industrial research communities. Capturing valid data from industry and relating the findings to academic studies is considered as a major challenge, which has not only impeded implementation but may result in uneven market digitization and facilitation of I 4.0 monopolies.

Similar to other studies this study is subject to limitations. The current study is limited by the number of articles included in the qualitative review and future work may benefit from including more articles from a broader range of interdisciplinary fields to clarify previously hidden complexities from a managerial lens. Also, given that the geographical focus of the study is general, future academic work on this topic may benefit greatly by focusing on a specific country or industry and provide cross comparison of results across firms in one industry sector or between similar industries in one country.

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