Knowledge management and digital technologies in the manufacturing industry: preliminary results from an empirical survey

Ardolino Marco*, Bacchetti Andrea*, Leoni Luna**

** Rise Research Laboratory, Università degli Studi di Brescia, via Branze 38, 25123, Brescia (marco.ardolino@unibs.it, andrea.bacchetti@unibs.it)*

*** Department of Management and Law, Faculty of Economics, University of Rome Tor Vergata, Via Columbia 2, 00133 Rome (Italy) (luna.leoni@uniroma2.it)*

Abstract: In today's rapidly evolving landscape, the convergence of digital technologies and knowledge management (KM) in the manufacturing industry has garnered significant scholarly attention. As digital tools continue to revolutionize organizational practices, their potential to enhance KM becomes increasingly apparent. To shed light on the relationships between the adoption of digital technologies and KM processes, an empirical survey in the manufacturing domain has been carried out. 83 complete compilations from senior executives of Italian manufacturing firms have been collected. Preliminary results call into question the theory that the level of implementation of digital technologies increases with the size of the companies. The results of the analyses also show a correlation between digital technology implementation and KM. This study not only contributes to the existing literature but also provides practical insights for practitioners aiming to navigate the intricate relationship between technology adoption and KM in the manufacturing industry.

Keywords: Knowledge management, Digital technologies, Empirical survey, Manufacturing, Industry 4.0

1. Introduction

The global manufacturing landscape is characterized by a dynamic nature, necessitating the development of adaptable strategies and technologies to keep pace with these changes. The integration of advanced technologies in manufacturing is poised to revolutionize not just the production and distribution processes but also to significantly impact various sectors such as workforce skills enhancement, environmental sustainability, income distribution, and overall social welfare (Núñez-Merino et al., 2020). Regardless of the manufacturing model implemented, it is crucial for firms to manage knowledge resources within the manufacturing context efficiently. By facilitating the sharing and reuse of both tacit and explicit knowledge, either internally or across different enterprises, organizations can significantly enhance their innovative capacities and core competitive strengths (Hoffmann et al., 2019; Manesh et al., 2020). Effective knowledge management (KM) can optimize resource utilization within an enterprise and enhance its design and manufacturing capabilities. Moreover, as the knowledge economy advances, the role of KM in manufacturing enterprises has increasingly gained prominence (Guo, 2009). Therefore, given that adaptability to changes is crucial for competitive processes, it is essential to integrate knowledge production with Industry 4.0 technologies to cultivate smart industries (Montoya-Quintero et al., 2022; Iheukwumere-Esotu and Yunusa-Kaltungo, 2022). KM can facilitate the adoption of these technologies by minimizing knowledge loss during implementation (Sartori et al., 2022; Oztemel & Gursev, 2020), fostering knowledge creation (Abubakar et al., 2019), and aiding decision-making processes (Núñez-Merino et al., 2020). In recent years, a significant number of scholars have contributed to the literature, promoting an effective blend of KM in the context of digital transformation (Ribeiro et al., 2022; De Bem Machado et al. 2022). Although there are indications of a link between KM and I4.0 enabling technologies, there remains a scarcity of empirical studies confirming this connection. Furthermore, the research often inadequately addresses how tacit knowledge is expressed and utilized in practice, particularly in relation to the new I4.0 technologies that facilitate the spread of knowledge within companies (Hoffmann et al., 2019; Manesh et al., 2020). This represents a significant research gap, given the practical importance of I4.0 technologies for KM (Ilvonen et al., 2018). Given these research gaps, further practical applications and empirical studies are necessary to understand I4.0's impact on KM more fully. This paper aims to investigate the adoption level of digital technologies, the benefits and obstacles pursued and achieved through them and the implementation of KM processes within manufacturing companies. This paper also aims to provide a preliminary overview of the relationship between the adoption of digital technologies and KM processes. To do this, a sample of 83 respondents to a survey of Italian manufacturing companies is analyzed. The remainder of this paper is organized as follows: Section 2 introduces the background of the research. Section 3 outlines the methodology used in the research, with the results presented in Section 4. Finally, Section 5 provides

conclusions and discusses potential future directions for this area of study.

2. Research background

2.1 KM in the manufacturing industry

Manufacturing companies today are striving to gain a competitive edge by tackling the increasingly complex task of managing knowledge processes within their organizations (Patalas-Maliszewska and Krebs, 2016). For this reason, an increasing number of manufacturing enterprises are recognizing the importance of managing and leveraging their extensive knowledge on manufacturing resource capabilities to enhance productivity, foster creativity, and address relevant issues through effective KM, transfer, and utilization within their operations (Wang et al. 2010). A substantial amount of manufacturing knowledge might be achieved through the daily production activities of manufacturing enterprises, serving as the cornerstone for their development (Wang et al. 2010). To become a knowledge-driven company, effective management of all categories of knowledge - within, across, and between business functions - appears indispensable (Shaw and Edwards, 2006). One of the primary objectives for manufacturing enterprises adopting KM is to enhance their innovation and responsiveness to market demands, thereby bolstering the core competitive capabilities of the organization (Qifeng, 2008). Hence, it's imperative for manufacturers to utilize knowledge resources by promoting the sharing and reuse of knowledge, whether within their own enterprise or among multiple enterprises (Zhang and Jin, 2012). This practice serves to enhance their innovative capacity and core competitiveness. Various KM implementation objectives and business domains necessitate distinct emphases and requirements for effective KM. Indeed, a plethora of research elucidates strategies through which manufacturing organizations can enhance KM processes. Scholars' discussion on KM in manufacturing organizations has delved into various facets, including benefits and positive effects on organizational performance (Zaid et al., 2023), competitiveness (Prashar et al., 2023), inter-organizational networking (Martins, 2016), and organizational learning. (Prashar et al., 2023). There is certainly no shortage of obstacles and barriers to adopting KM processes within manufacturing companies. One of the primary challenges in implementing KM might be the lack of awareness and limited time (Singh and Kant, 2008). Furthermore, most of these barriers can be related to personnel issues, including internal resistance, trust concerns, fear of exploitation, and scepticism (Cheng and Fu, 2013).

2.2 KM and digital technologies

The advancements brought by the introduction of digital technologies enhance the capability to scan and identify significant information, thereby fostering the development of advanced applications of current knowledge in organizations (de Bem Machado et al., 2021). From these advancements, novel KM strategies may arise (Tortorella et al., 2023). Indeed, KM focuses on processes of distribution, creation, and sharing of knowledge, together with knowledge flow (Alavi and Leidner, 2001). Thus, strong linkages can be observed between knowledge and KM and some of the principles of I4.0 that stress networking, connectivity, and interface in physical or digital formats (Culot et al., 2020). Therefore, organizations possessing exceptional KM capabilities can swiftly act in dynamic business settings and attain competitive advantage (Koh et al., 2022). On the one hand, the spread of I4.0 conduces to increased agility and fluidity in communication, helping complete tasks, or achieving savings and, specifically, knowledge (Alonso et al. 2024). Organizations are exploring the ways in which KM, combined with innovative data and process management technologies, can enhance Industry 4.0 (Bordeleau et al., 2020). On the other hand, KM can enhance the effectiveness of adopting digital technologies such as Artificial Intelligence (AI) (Leoni et al., 2022). The role of KM can thus support analytical processes, leveraging the vast amounts of data generated and disseminated through increased automation and big data usage (Schiuma et al., 2020; Buccieri et al., 2020). Combining data and knowledge facilitates automatic reasoning, the incorporation of digital technologies, and the development of decision support systems that assist employees at various decision-making levels (Meski et al., 2019). Li et al. (2019) suggested that an organization implementing I4.0 needs to generate, acquire, and adaptively disseminate knowledge to swiftly adapt to unpredictable market scenarios better than its competitors. Similarly, as organizations adopt digital technologies, they might establish tailored practices to manage knowledge at the individual, team, and organizational levels, basing their decision-making on more precise data (Tortorella et al., 2020). In addition, the adoption of I4.0 technologies can positively impact work flexibility and autonomy, thereby boosting job performance as well as creativity and innovation (Cassia et al., 2020). However, the acquisition and dissemination of knowledge within an organization, particularly on the production floor, still relies heavily on the employees (Ribeiro et al., 2022). As such, KM and digital transformation together play a pivotal role in shaping organizational culture and fostering innovation (Sartori et al., 2022). Additionally, KM facilitates the development of skills and competencies essential for I4.0 by promoting knowledge exchange between experts and beginners (Zangiacomi et al., 2020) and supporting training and organizational learning (Oztemel & Gursev, 2020).

3. Methodology

3.1 Sample unit

This study focuses on Italian manufacturing businesses and local branches of multinational firms as the main subjects of examination. 83 complete responses have been collected from senior executives of Italian manufacturing firms, without restrictions on company size, including micro, small, medium, and large businesses across various industrial sectors. The varied selection of the sample is advantageous for this preliminary investigation as it seeks

to offer significant perspectives on the subject matter (Forza, 2002)

3.2 Data collection method

The survey took place from November 2023 to March 2024. Predominantly, personnel from R&D, General Management and Executive roles, IT Systems, and Production were engaged. Overall, 83 companies participated. An analysis of the business sectors of the respondents highlighted the roles most actively involved in the survey: CEOs represent 43% of the respondents, followed by CIOs and CTOs with 20% of responses. Supply chain, Planning and Purchase Managers accounted for 10% of participants, while R&D and Innovation managers answered in 7% of instances. The remaining 19% of responses came from other roles, including those in Quality, Safety, Production, Marketing and Sales.

3.3 Sample description

Sample description is represented in Table 1. Overall, a sufficient heterogeneous classification has been achieved, since more than 50% of the sample is represented by large companies, and the others are SMEs. Moreover, different manufacturing sectors have been included.

Table 1: Sample description

Enterprise size	**Number**	**Percentage**	**Classification Criteria**
Small and Medium	38	46%	Revenue < 50 mln euro
Large	45	54%	Revenue > 50 mln euro
Industrial Sector	**Number**	**Percentage**	**Classification Criteria**
Machinery for industry not elsewhere classified	30	36%	NACE 28
Metal products. except machinery and equipment)	15	18%	NACE 25
Rubber and plastic	9	11%	NACE 22
Electrical equipment	8	10%	NACE 27
Computer. electronic and optical products	3	4%	NACE 26
Textile	3	4%	NACE 13
Motor vehicles. trailers and semi-trailers	3	4%	NACE 29
Other non-metallic mineral products	2	2%	NACE 23
Others	10	12%	Others

3.4 Questionnaire structure and items

A questionnaire with mixed open and closed questions has been sent to companies through a web survey technique. The questionnaire was structured in 10 sections, namely: i) General information of respondent; ii) General information of the company; iii) Adoption and implementation of digital technologies in the companies; iv) Benefits of adopting digital technologies; v) Challenges and barriers in adopting digital technologies; vi) Adoption and implementation of KM processes. Regarding the level of adoption of digital technologies, the status, if any, of implementation of the following technologies was investigated: Internet of Things (IoT); Additive manufacturing (3d printing); Augmented and virtual reality; Big data analytics; Collaborative robotics and advanced man-machine interfaces; Blockchain; Artificial intelligence (Machine learning. Deep learning. ...); Automated guided vehicle (AGV); Simulation models / Digital twin. For each technology, the respondent was asked to define a level of adoption (to which a numerical value was attributed) from the following: 5 – Usage; 4 – Investment planning and/or implementation in progress; 3 – Technical-economic feasibility analysis; 2 – Preliminary study; 1 – No action taken. The level of benefit pursued and experienced by the adoption of digital technologies, as well as the challenges, was investigated using a Likert scale of 1-5. The following benefits were investigated: Increase in turnover; Reduction and/or optimization of costs; Increase in efficiency and productivity; Increase in product and process quality; Increase in flexibility in the customization of products and services; Increase in customer service level; Higher competitiveness compared competitors; Acquisition of new customers; Opening of new business opportunities; Being more resilient and learn from data; Implementation of processes devoted to reactivity, proactivity and predictability. These are the challenges that were investigated: Lack of financial resources and excessive costs; No clarity of the economic advantage and benefits; Lack of qualified personnel; Lack of interest and commitment of top management; Lack of government support and policies for digital technologies adoption; Poor quality of existing data; Poor IT infrastructure and Internet network; Compatibility and integration issues; Cybersecurity issues; Inadequate maintenance support system; Lack of an adequate KM system. Regarding the adoption of KM processes, through a Likert scale (1-5), the respondent was asked to rate a series of sentences, each inherent to one of the five KM processes, namely: Knowledge acquisition, Knowledge creation, Knowledge usage, Knowledge storage, and Knowledge sharing. A technology implementation level has been calculated for each respondent as the average of the values corresponding to the degree of use of all the technologies investigated. Likewise, a level of implementation of KM processes was calculated resulting from the average of the values of the individual KM processes investigated.

4. Results

4.1 Digital technologies implementation level

According to Figure 1, Additive Manufacturing (AM) and the Internet of Things (IoT) emerge as the most frequently utilized technologies within the sample, with 35% and 34% of the companies implementing them, surpassing Big Data Analytics and Collaborative Robotics, which stand respectively at 17%. The adoption rates for Automated guided vehicles (AGV) and Simulation and Digital Twin are at rates of 16% and 13%, respectively. The other technologies are used by less than 10% of the sample. It is interesting to note that the trend with respect to the most used digital technologies remained largely unchanged from

a similar study conducted in the past (Zheng et al. 2020; Zheng et al. 2021).

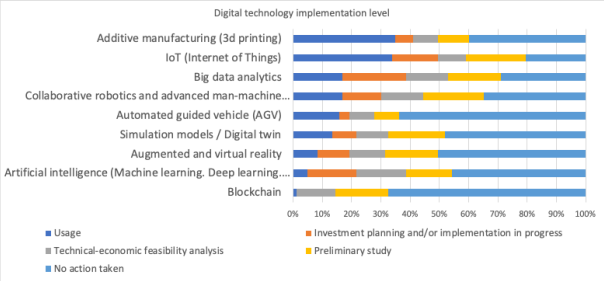

Figure 1: Digital technology implementation level

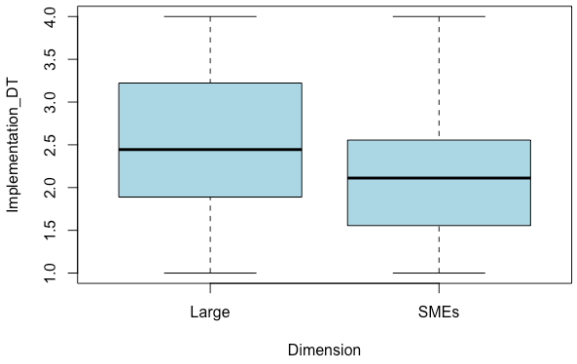

Figure 2: Digital technology implementation level vs. Company dimension

The same cannot be said, however, regarding the correlation between the level of technology adoption and firm size. Although Figure 2 would justify a correlation between firm size and the level of technology adoption, conducting a Welch Two Sample t-test, the analysis yielded a t-value of 1.9413 with 79.457 degrees of freedom, and a p-value of 0.05576, which marginally exceeds the conventional alpha level of 0.05.

4.2 Benefits in the adoption of digital technologies

Figure 3 illustrates the benefits most sought by enterprises in the sample. This analysis includes both responses from those companies implementing and not implementing digital technologies. The findings indicate that performances in the shopfloor are the foremost anticipated benefit (efficiency and productivity; product and process quality) followed by customer service level. These results underscore that Italian manufacturing firms are predominantly inclined to exploit digital technologies to produce high-quality products with high efficiency. In contrast, digital technologies are seen as relatively less important for increasing business volume, building new business opportunities, and increasing revenue. It is also interesting to underline it is interesting to see if there are any differences and relationships between the perceived benefits and the level of implementation of digital technologies. Indeed, by conducting a correlation test, the correlation between the level of implementation and perceived benefits is statistically significant, although with a moderate effect. Indeed, the analysis of Pearson's product-moment correlation between benefits perceived and the implementation level of digital technologies indicates a positive correlation of 0.2771. This correlation is statistically significant with a p-value of 0.0112, suggesting a modest but statistically significant positive relationship.

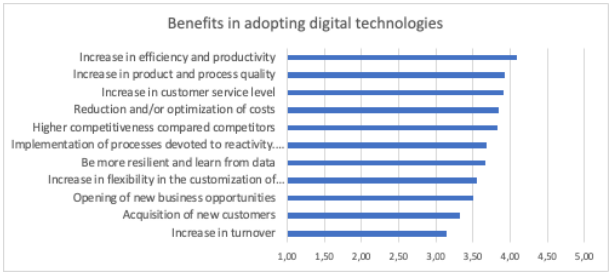

Figure 3: Benefits in adopting digital technologies

4.3 Challenges in the adoption of digital technologies

This section identifies the barriers that enterprises face when implementing digital technologies. According to Figure 4, the sample of respondents indicated that a lack of qualified personnel and no clarity of the economic advantage and benefits represent the most significant hurdle to practical adoption. This finding aligns with enterprises' difficulty in acquiring the right skills and competence to both effectively use and evaluate the potentialities of digital technologies. Interestingly, digital skills are still one of the most inhibiting barriers with respect to the adoption of digital technologies, and thus a full alignment with respect to the principles of Industry 5.0 that looks more at employee's skills and competencies. In contrast, cybersecurity issues, and IT structure and the Internet are considered among the least inhibiting factors with respect to the implementation of digital technologies. Replicating the correlation analysis between the level of technology implementation and barriers results in an analysis that is not statistically significant, as the p-value is 0.07539. Thus, it cannot be said a priori that there is a difference in the obstacles feared among those who do not implement versus those companies that do have a high average level of implementation.

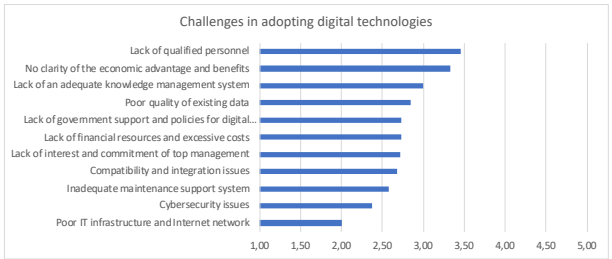

Figure 4: Challenges in adopting digital technologies

4.4 KM processes implementation

The results clearly demonstrate that manufacturing enterprises are better at using and creating knowledge than preserving and sharing it within the organization (Figure 5). This finding is fully consistent with the current complexity faced by many organizations, which must manage

increasingly larger amounts of data and information in ever more complex and turbulent contexts.

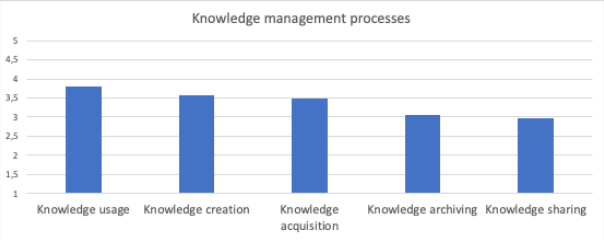

Figure 5: KM processes

Evaluating the relationship between the implementation of KM processes and company size reveals a strong correlation (Figure 6). Indeed, the Welch Two Sample t-test, showed a statistically significant difference with a p-value of 0.03693, indicating that the difference in means is statistically significant at the 5% level. Therefore, smaller enterprises are notably more adept at managing knowledge than larger ones. This aligns with the theory that larger organizations often face increased complexity due to a higher number of employees and, sometimes, greater volumes of data and information to manage. Moreover, perhaps more crucially for this research, there is a positive correlation between the level of digital technology implementation and the extent of KM processes. Indeed, Pearson's correlation analysis revealed a significant positive correlation with a coefficient of 0.536, indicating a moderately strong relationship. The extremely low p-value of approximately 1.735946e-07 strongly suggests that this correlation is statistically significant and not due to random chance. It is thus evident that there is a strong relationship between these two constructs.

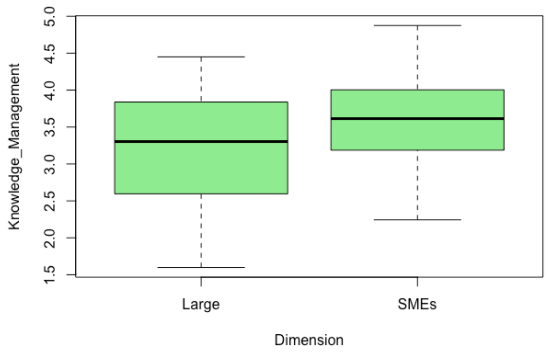

Figure 6: KM implementation level vs. Company dimension

5. Discussion

The findings from this research offer insights for practitioners in the Italian manufacturing industry sector, highlighting the current state of digital technologies' adoption. The high adoption rate of additive manufacturing and IoT suggests a clear focus on improving operational efficiency and real-time monitoring. Therefore, manufacturers are prioritizing technologies that provide immediate, tangible benefits on the shop floor, such as enhanced productivity and process control. Nevertheless, the lack of a correlation between firm size and technology adoption trials the usual idea that larger firms have an advantage to implement advanced technologies due to their higher financial and economic resources. This insight suggests that strategic priorities, sector-specific needs, and perhaps even organizational agility play crucial roles in technology adoption. For practitioners, this means that smaller firms should not be deterred by their size but should instead focus on leveraging their inherent flexibility and niche advantages to implement digital technologies effectively.

The focus on operational benefits, such as efficiency, productivity, and quality, emphasizes a predominant operational attitude. While these are crucial, it is essential for manufacturers to also contemplate the strategic potential of digital technologies in driving innovation, exploring new markets, and creating additional revenue streams. Companies should therefore enlarge their digital strategy beyond immediate operational advantages to embrace long-term growth and competitive advantage.

The barriers identified, particularly the lack of qualified personnel and unclear economic benefits, highpoint critical areas for intervention. Companies must invest in targeted training programs to bridge the skills gap and improve their ability to evaluate and communicate the economic advantages of digital technologies. This aligns with the Industry 5.0 framework, which emphasizes the integration of human skills and competencies with advanced digital technologies.

The insights concerning KM practices show that smaller enterprises are more effective at managing knowledge compared to the larger ones. This finding recommends that small firms benefit from less complexity and more efficient and streamlined communication channels. Manufacturers in larger organizations should consider adopting more agile and flexible KM practices to overcome the inherent challenges of size and complexity. In addition, the strong positive relationship between digital technology implementation and KM processes underlines the cooperative potential of integrating these two areas. For practitioners, this means that investing in digital tools for KM can significantly enhance organizational learning, innovation, and responsiveness.

Finally, the theoretical implication of this study lies in challenging the assumption that firm size is a primary determinant of technology adoption. Our research findings suggest that agility, strategic focus, and sector-specific factors are equally, if not more, important. This insight contributes to the broader discourse on digital transformation by highlighting the nuanced interplay between organizational characteristics and technology adoption.

6. Conclusions and limitations

This research assessed how Italian manufacturing firms are positioned concerning the adoption of digital technologies and implementation of KM processes. Like any research, this study has its limitations. Firstly, although the Italian manufacturing sector predominantly comprises SMEs, this group has not been specifically targeted for investigation. Additionally, despite our thorough review, we have not proposed any reference model or framework. Furthermore,

given the limited number of samples in this study, additional sampling is needed to provide a complete analysis of the situation. Initially focusing on Italy, but subsequently extending to other countries, this would allow for comparative assessments and a deeper understanding of the context. Efforts will be made to develop both managerial and practical references to aid Italian manufacturing companies in consolidating and enhancing their competitive stance on the global market.

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