

DIGITAL TRANSFORMATION IN SMALL AND MEDIUM-SIZED MANUFACTURING BUSINESSES IN QUEBEC (CANADA): SOCIOECONOMIC IMPACT AND SUSTAINABILITY

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ABSTRACT:

Industry 4.0 is a global revolution that is transforming manufacturing processes to meet the demands of expanding production and to maximize the creation of value. This involves increasing automation as well as machine autonomy and interconnectivity, a concept known as the Internet of things, or IoT.

Although the digital era and especially Industry 4.0 are raising numerous challenges, integrating production, distribution, and informational processes represents huge opportunities for businesses and consumers alike. The combination of technologies that will allow individual companies to benefit the most from these changes will depend on the specifics of each situation. The socioeconomic impact of the IoT can be positive or negative for businesses, and evidence is mounting that small-to-medium-sized enterprises (SMEs) are at greater risk of experiencing negative impact, since they operate under constraints that limit their ability to evaluate the best technological choice for their context. To help these businesses manage a successful transition to Industry 4.0, we are studying the experiences of Quebec SMEs with digitization, and their implications for sustainable development. In this article, we present a review of the literature on the evaluation criteria and indicators of the socioeconomic impact of digitization on SMEs, and the findings of our inquiry conducted among Quebec SMEs, which confirm some of the key concepts described in the literature on the opportunities and dangers associated with the digitization of manufacturing.

KEYWORDS:

1. Digitization
2. Socioeconomic impact
3. Sustainable development
4. Industry 4.0
5. Small or medium-sized manufacturing
6. Quebec (Canada).

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1. Introduction

Corporations, be they privately or publicly owned and operated or anywhere in between, play a fundamental and crucial role in the economic development and hence the standard of living of any nation (Tremblay et al., 2018). They provide employment through investment and thereby reduce poverty as well as economic dependence. New economic pressures, increasing competition and a more dynamic economic environment are emerging as technological progress changes how businesses function (Badri et al., 2018). Manufacturing companies everywhere now face the same dilemma: should they try to maintain the status quo, or should they invest in the never-ending search for possible improvements through technological means? The latter option seems better advised, since it is difficult to imagine how a business that does not evolve will survive.

To ensure its continued improvement, an enterprise will invest in new production units or means of commercialization and will develop techniques of rigorous management of its operations or technological projects. Such management is based on skills, human and financial resources, equipment, and technological tools to monitor the progress and ensure the success of the project within the cost, quality, and temporal objectives (PMI, 2016).

For some SMEs, modernizing while maintaining their commitment to profitability and financial soundness will involve not only research and development but also digitization of their operations, an upgrading of operations that requires the integration of several technologies to achieve success. This

transformation will allow them to harness innovations that will have a positive impact on processes they already practice as well as implement new processes (Badri et al., 2018).

Although digitization represents huge developmental potential for SMEs in manufacturing, it carries a risk of hindering the sustainability of operations. A company must also learn to minimize the negative impact of their activities on their financial resources and on their immediate social environment. This will be addressed holistically by using suitably adapted new technologies, new managerial methods, and new relationships between the various stakeholders (MEI, 2021).

New technologies are revolutionizing the functioning of SMEs. The changes are creating value and improving productivity. Competitiveness is stimulated and operational capability is improving (Bédard-Maltais, 2021). Several approaches to ushering change into businesses have been developed. Most are not innovative, technologically audacious, or very profitable. Many companies monitor the changes occurring around them but remain spectators (Gamache et al., 2019). Some ignore technological progress entirely because of lack of resources or because they are by nature opposed to change.

Companies that exhibit limited use of technologies and data and a very average digital culture typically also display a lack of vision and strategy. It is unclear how a business can thrive while disregarding issues raised by the worldwide transition to digitization and not integrating these into its strategies with regard to products, services, operations, and work methods (Gamache et al., 2019).

The digital revolution is putting pressure on SMEs to step out of their comfort zone and change their production models and process management methods. Tasks based on new technologies offer greater autonomy and flexibility to workers. However, this is not without drawbacks such as work intensification by increasing hours worked and stress (Ben Aziza et al., 2021; Badri et al., 2018). These new forms of employment can oblige workers to be available at any moment and any workstation. The new technologies are abolishing the traditional boundaries between jobs.

SMEs are using new technologies more and more, depending on the sector of activity, to increase efficiency and productivity, to optimize their supply chains, and to gain access to new markets. However, as such use becomes very widespread, the organization of work, employment and the workplace undergo profound transformations (David et al., 2017). New activities that stimulate the economy are created, while growth in production tends to be unstable, making many jobs precarious or in some cases obsolete (Vedrenne, 2016).

All SMEs that wish to integrate digitization and the management thereof into their operations must ask themselves an important question: how will they monitor the socioeconomic impact of this initiative, and thereby take full advantage of the opportunity and minimize the dangers, particularly in terms of sustainability?

The principal subject of the present article is the socioeconomic impact of adopting advanced digital information processing technologies in small-to-medium-sized manufacturing companies in Quebec. Our secondary focus is on identifying the criteria and indicators that are best suited to the measurement of this impact and on showing to what degree the opportunities offered by the digitization of manufacturing operations outweigh the drawbacks. In the sections below, the literature search methodology is described, followed by the results of the search and of our direct querying of several SMEs, discussion of the results and the limitations of this study, and finally a general conclusion.

2. Methodology

The research was conducted in several steps (Fig. 1), beginning with the literature search to identify criteria and indicators relevant to our subject. From this list, a questionnaire was created for the purpose of evaluating the potential impact of adopting advanced digitization technologies in the Quebec SMEs surveyed. A descriptive analysis was then carried out to allow us to characterize the views that managers have of the transformation of their businesses.

This study is descriptive in nature and does not aim to conduct a comparative analysis. It focuses solely on a sample of manufacturing SMEs located in Quebec. The objective is to explore the specific context and challenges of digital transformation within this regional and industrial scope.

Insert Fig. 1 here

2.1. Review of the literature

The state of current knowledge on digitization of operations in small or medium-sized manufacturing companies and the socioeconomic impact thereof was evaluated by examining research articles published in related fields such as industrial relations, social psychology, occupational health and safety, economic, environmental sciences and so on.

Search engines such as Google, Google Scholar and Scopus allowed us to target scientific articles, research reports, technical reports, and scientific conference proceedings relevant to digitization, Industry 4.0, Internet of things, SMEs, and sustainable development to ensure full coverage of the subject area. Documents dating from 1978 to 2019 provided a chronology of the evolution of the global economy and industry worldwide.

2.2. Characterization of the socioeconomic impact of digitization

This exercise yielded important information on the transformation that Quebec SMEs have undergone during recent decades and guided the design of the questionnaire used to evaluate the impact of the digital technologies implemented. The types of impact thus identified and analyzed allowed us to compile a nearly exhaustive list of elements relevant to the situation of the SMEs surveyed.

2.3. Compilation of the socioeconomic impact evaluation criteria and indicators

Criteria and indicators of the various aspects of the impact of digitization were readily identified in the literature. This provided an overview of the opportunities to improve the situation of a company both socially and economically. However, it should be noted that the indicators described in the literature apply only to evaluating potential socioeconomic impact. In addition, the stakeholders in this research are interested only in indicators that are relevant, valid, reliable, and measurable, whether qualitative or quantitative.

2.4. Survey of SMEs in the Québec manufacturing sector

Based on the elements of impact and indicators thereof, a questionnaire suitable for querying managers of Quebec SMEs and digitization projects therein was developed. Consisting of four sections, it contained questions for identification purposes, on the type of business, on the impact of digitization, and on measurement of the impact. The responses were analyzed to enrich the discussions and summarized to allow comparison of the reality noted in the field with the theories defended in the literature.

The survey of company managers was conducted in full confidentiality and protection of the participants' personal information. The survey, analysis and follow-up processes were in full compliance with the terms of the certificate of ethics granted by the UQTR research ethics committee (CER-20-272-07.13).

2.5. Analysis and discussion of the SME survey result

Interpretation of the data focused especially on relationships noted between variables, based on statistical analysis using commercial software, which also provided graphic visualization as well as the tabulation of results. The principles drawn from the literature were then confirmed or infirmed accordingly.

3. Results

3.1. Issues raised by Industry 4.0

Today's manufacturing industries use huge amounts of structured, unstructured, and inadequately interconnected data in ways that are often ill-adapted to meeting all expectations of their clientele and creating added value (Gaudron and Mouline, 2017). Since interconnection of the structures within an organization is essential for obtaining a single, uninterrupted data stream, an SME must consider the challenges listed below (Fig. 2).

Insert Fig. 2 here

These challenges may be summarized as follows (Cayrat, 2018; CGI Group, 2017):

- Company staffing: To implement Industry 4.0 solutions, new employees must be hired, and new skills developed. As daily tasks and many manual tasks disappear, new roles are created. Warehouse and stock management are robotized, and the remaining staff must learn to work in the presence of robots and with the new processes. At least one skilled programmer of robots is needed.
- Raising of awareness: Most owner/managers of small manufacturing companies remain unaware of the opportunities that Industry 4.0 offers.
- Collaboration: The key to success is cooperation between the company and its suppliers using information technologies. Industry 4.0 solutions are provided through an ecosystem of suppliers, system integrators, and start-up companies.
- Investment: Implementing Industry 4.0 solutions or updating existing systems requires adequate funding. A nation must consider this reality for its economy to survive in the worldwide competition.

- Modernization (of information technologies): Future technologies will likely combine several tools of planning, operations management, and digital control. Processes will be controlled by systems based on ever more advanced information technologies.
- Standardization: Standards must be adapted, and new standards defined, since existing means of manufacturing often do not support complete and safe upgrading to Industry 4.0 methods.
- Cyber security: Direct digital control of industrial processes requires instantaneous detection and response without compromising the flexibility of the enterprise. Such control systems will be highly integrated and require commensurate network security, since the more a company innovates, the greater is the risk of harm due to data theft or subversion. Security will become a competitive asset in SMEs in the manufacturing sector.

3.2. Industry 4.0 technological tools and strategies

Several strategies of successful transitioning towards Industry 4.0 are already widely known. These may be categorized as prospective, analytical, and defensive (Gamache et al., 2019; Raymond et al., 2009; Miles et al., 1978). A prospective strategy is one whereby new products and services are introduced, new markets are sought, and economic models are revised, and is based on flexibility and agility to maintain satisfactory profitability. The aim of an analytical strategy is to guarantee effective performance through the development of efficient and flexible infrastructures that allow quick reaction to change to keep costs down and maintain or improve product quality. A defensive strategy is adopted to secure market share. The company is focused more on positioning itself in the market and on competitive pricing.

In the case of transitioning towards Industry 4.0, it is therefore fundamental to choose a strategy that implies the development of technological tools through acquisitions that will orient company operations towards the achievement of its goals. A company must first fully understand the potential of the tools for improving its performance (CEFRIO, 2016).

Among the principles to emerge from this revolution are proper planning to implement digitization projects by integrating them as innovations for transforming and improving processes and managerial methods and for in-house development of new skills. The technological tools used to upgrade a business to Industry 4.0 capability have been the subject of much discussion (Valette et al., 2020; Haenlein and Kaplan, 2019; Badri et al., 2018; Bagheri and Lee, 2015; Cardon, 2015; Yue, 2015; Claverie and Fouillat, 2010; Benghozi et al., 2008). Those most relevant to the SME context are listed below (Table 1). They offer numerous advantages to such enterprises, for example, faster and more efficient data processing to fuel innovation and increase the flexibility of industrial production systems.

Insert Table 1 here

Each tool is categorized in terms of the context in which it is used (Blanchet, 2016). For example, simulation software, computer-assisted design and product lifecycle management are included under product and process design, whereas piloting and control tools encompass cyber-physical systems, the Internet of things, and traceability and process management software (Gamache et al., 2019). At yet a higher level of sophistication, the use of intelligent and autonomous machines, collaborative robots and additive manufacturing may be integrated into production operations to improve quality and system flexibility. Services include tools of predictive maintenance that now use Big Data.

The most widely used software categories appear to be office packages, drawing programs, managerial software, and social media (CEFRIIO, 2017). Businesses that integrate certain digital tools into their operations note a significant positive impact on their daily product design and manufacturing activities in 54% of cases (Gamache et al., 2019).

3.3. SMEs and Industry 4.0

Regardless of its size, the primary function of a business is to produce wealth. An SME has fewer resources at its disposal and must optimize its production to achieve the highest operational efficiency possible. Even a small corporation must remain able to distribute its income to its staff and in most cases pay dividends to its shareholders. And if profitable, it also pays corporate taxes to the state (Duchéneau, 1996). SMEs play a major role in providing employment to the citizenry of the nation, and particularly in job creation, and thus contribute substantially to the functioning of society (Government of Canada, 2015). When SMEs suffer economic losses or fail, unemployment rises, and people suffer a drop in quality of life. Even as a SME prospers, it must remain mindful of the well-being of its staff and of the quality of the work environment that it provides (Badri et al., 2018). Working conditions must be acceptable, even when the work is difficult by its nature and disruptive of family life, such as night shifts. While creating wealth, a SME cannot focus entirely on bottom-line profit. It must also not damage the environment and should support the economic and societal development of the nation.

Modernization of industrial SMEs by implementing technological innovations has been the focus of many studies around the world. To limit the drawbacks while benefitting from the opportunities created for SMEs through technological advances, a strategy for analyzing competitive position with the environment taken into consideration has been proposed (Porter, 1979). This strategy is predicated on the advantages associated with enabling customers and suppliers to negotiate, compete and respond to substitutions of products and services. The SME can thus increase its capacity for creating value as it becomes more competitive, modernized and closer to its clientele (Amar, 1987). Integration of new production equipment and communication/information processing technologies

makes it possible to generate data and related services. SMEs become more and more intelligent and hence a more efficient, safer, and ecofriendly network (Strozzi et al., 2017).

An intelligent SME has been defined as an organization that provides a flexible and adaptive production process and is able to solve problems inherent in manufacturing quickly and without strain, thus blurring the boundaries of industrial business transactions as they have been understood up to the present (Radziwon et al., 2013). An SME can be based on automation controlled using computers and software and extendable as needed to optimize production or use of resources, while remaining open to the implementation of mechanisms of cooperation with other players in the industry (Radziwon et al., 2013).

The range of technological means that an SME can integrate into its manufacturing capability is vast (Strozzi et al. (2017). This increases interactions between machines and humans, use of the Internet of things, artificial intelligence, and so on, as well as the volume of information transmitted in real time, stored, and shared within the network. The skills of staff improve along with operational agility and efficiency.

Although the transition to Industry 4.0 appears to be wholly beneficial, it does not come without inconveniences for the functioning of SMEs, due in particular to the limited availability of technological skills and specialized expertise (Kohler and Weisz, 2016). Another problem is the rapid pace of technological progress and hence the risk of early obsolescence of the investment. On the macroeconomic scale, replacing workers with machines can distort labor market dynamics and exacerbate inequalities. Although new innovative technological businesses may be created, some of these should have the potential to grow into larger businesses that compete in international markets (Krachtt, 2018). They must have the wherewithal to devise competitive strategies to become profitable and sustainable.

Certain business processes and practices and digital tools have greater impact than others on the performance of SMEs in the digital economic sphere (Gamache et al., 2019). Among the Quebec SMEs surveyed, 71% indicated that they are not fully ready for complete digitization of their operations. In an inquiry conducted by the Quebec ministry of the Economy and Innovation (MEIQ) on how Industry 4.0 is perceived, 63% of the companies surveyed indicated that the impact of Industry 4.0 on their business will be minimal, and 31% indicated that they have no plans for such a transition, believing it to be unnecessary (MEI, 2019).

3.4. Managing digitization projects

In a survey conducted several years ago, 50% of company directors counted digitization among their strategic objectives (Bidet-Mayer (2016), reflecting the consensus that all organizations need to be focused on customers to guide the change successfully (Gaudron and Mouline, 2017). The approach

to digitization must be multifunctional, to allow integration of products and services, material and software throughout the life cycle of the product (Gaudron and Mouline, 2017). However, for such a project to be managed effectively and efficiently, the strategy must be highly focused and specialized. A five-step approach to digitization has been successful in SMEs. A key step is the audit to evaluate the current status of the business based on its operational and organizational capabilities, to match the project objectives with the opportunities and advantages sought. The planning step includes preparing detailed plans for each improvement phase and ranking these according to their material, funding and labor requirements. Next, the strengths and weaknesses of the project are noted and corrected in accordance with precise milestones. The implementation of each phase throughout the organization will mark the beginning of the project in the concrete sense and deployment of all the resources needed for success. The project concludes with optimization based on the setting of new priorities, follow-up protocols, adjustments and fine-tuning.

3.5. The SME and sustainable development

Numerous economic and organizational theories have been applied to analyzing business strategies from a sustainable development perspective. These can be grouped into two methodological paradigms, namely classical economics and sociological (Capron and Quairel-Lanoizelée, 2006). The former combine and focus on the relationship between stakeholder theory and the theory of dependence on resources to incorporate strategies having real impact (Hannan and Freeman, 1984). The latter combines new sociological theories based on organizational decision-making (Oliver, 1991; DiMaggio and Powell, 1983). Approaches based on resources have been used more effectively to evaluate the commitment of businesses to sustainable development (Barney, 1991).

Most of this research, in general as well as from the sustainability perspective, has focused on large corporations. The SME experiences a somewhat different reality, since it may face specific and insurmountable obstacles to effective integration of sustainability strategies, even when sufficient awareness has been raised and an explicit commitment is expressed. However, some SMEs have crossed this bridge and obtained satisfactory results in all respects, notably visibility, improvement of public image, customer loyalty, and operational performance (Gamache et al., 2019).

From the sustainability perspective, the strategy of transition to digitization must consider numerous social factors (Gouvernement du Québec, 2019). Sustainability goals were set by the UN in broadening its millennial goals for world economic development (United Nations, 2015). The economic goal is to favor the growth and efficiency of businesses by promoting good practices and reinforcing commercial relations through sustainable consumption (Gouvernement du Québec, 2019 ; United Nations, 2015). On the social side of the equation, sustainable development implies participation of societal groups in

questions of health, consumption and employment to meet human needs and move towards social equality.

Almost all sustainability goals are clearly designed to ensure an efficient and sustainable industrial transformation. This includes creating long-term and adequately paid jobs, disincentivizing unstable jobs and improving occupational health and safety (United Nations, 2015). Sustainability is a key aspect of industrial manufacturing in the digital era, and is problematic both in developed and developing nations.

Commitment to any approach to sustainable development is voluntary and does not necessarily bring any tangible advantage outside of the realm of compliance with legislation. Pressure felt within an SME (e.g. motivation of directors or some staff) is a major motivator for integration of the principles of sustainable development (Blais, 2011). Respect of environmental legislation is nevertheless encouraged in some SMEs, as much as cost reduction and strengthening relations with the public (Gadenne et al., 2009).

Table 2 summarizes the advantages of applying the principles of sustainable development in the context of digitizing the operations of an SME (Blais, 2011; Delchet, 2007).

Insert Table 2 here

3.6. Socioeconomic impact of digitization projects

Digitization of a business encompasses all the transformations necessary for a company that uses primarily pre-computer-age methods to convert all its operations to digital culture (Autissier and Metais-Wiersch, 2016). Such a business must rely on adapting or completely revising old models to launch the transformation while remaining competitive. Up to the present, the most widely used definition of digitization has been that proposed by Chaintreuil and Le Gall (2015): a structured initiative by which an organization adapts its value proposition, its business model, its strategies, its operations and its technologies to the fundamental changes brought by digital technologies. This involves orienting the entire organization coherently towards the new needs of users influenced strongly by digital technologies.

Digitization is a profoundly revolutionary project, fueled by the constant winds of change and pushed into overdrive by the rise and dynamism of the Internet, the limitless potential of information and communication technologies, and the relentless pressure on managers to improve the bottom line (Lemoine, 2014). Digital technology and digitization are thus not necessarily indivisible, but distinct elements that are combined to resolve technological constraints within businesses (Caudron and Van Peteghem, 2014). The principal drivers of digitization are at the same time increasing sales and reducing costs. The drawbacks of digital technology are numerous. Security issues (cyber attacks),

reliable funding (unpredictable budgetary constraints), staffing challenges (lack of skills, organizational difficulties), business agility problems (archaic managerial models) are often cited.

As new technological tools arise, such as the Internet of things, Big data, the Cloud, and Robotics, the concept of digitization continues to evolve (Ben Aziza et al., 2021; Badri et al., 2018). For this revolution to succeed in a given business, numerous challenges must be met (Kohler and Weisz, 2016). Workers may find in it rewarding employment and career opportunities based on the development of new skills and collaboration with people they would never otherwise know. Businesses will reduce costs and increase productivity by replacing staff with software and by performing new and lucrative tasks made possible by their automation capabilities (OECD, 2017).

Several emerging tendencies in the deployment of new labor models, tools and digital processes during the transition period, including social development, all improving the positive impact of digitization projects in SMEs, have been summarized in a monograph (Menger and Paye, 2017). Over the decades, thanks to the combined knowledge and technologies drawn from a wide range of fields, analysis of the socioeconomic impact of digitization, especially the social and economic dimensions, has improved considerably (Menger and Paye, 2017).

3.7. Social impact of digitization in SMEs

Stressful work and strained workplace relations decrease quality of life and can affect the mental and physical health of workers (Ben Aziza et al., 2021; Badri et al., 2018). Since digitization is at the same time a social and technological revolution, increasing the proportion of temporary work and unemployment, lowering salaries, technologically transforming the workplace, and creating new social pressures that could degenerate into social unrest, workers' rights will have to be redefined.

Among the pioneers of reflexion on the social function of the workplace, 19th-century utopist philosophers Charles Fourier (1772–1837) and Jean-Baptiste Godin (1817-1888) imagined an ideal society in which work was a harmony of pleasure and agreement. Their conception of the workplace is said to be the root of modern business management concepts such as Lean, agile methodology, and collaborative management. They could not have anticipated how digitization and the resulting social networking would drive the evolution of the workplace and redefine working conditions, workplace location, occupational health and safety, tool user-friendliness and task flexibility, and that the traditional bases of production would simply disappear, replaced often by processes never touched by a human hand. In this sense, digitization can be beneficial to the environment, but if the workplace does not have built-in job security during the period of transition, workers and their families and communities can face hardship and the threat of social collapse (Badri et al., 2018).

Much of the research on this subject has been focused on the case of the most developed countries. By reducing the need for direct input by humans, digitization could help nations achieve the 1960s

dream of a leisure-based society, whether we still want that or not. In the USA, for example, most work could be automated over the next few decades (Frey and Osborne, 2017). In the worst case scenario, about 50% of jobs will be seriously threatened over the next 15 to 20 years (Pochet, 2017). At best, only about 10% of jobs will be threatened, while half will undergo profound transformation (Arntz et al., 2016; 2017).

The impact on work could be more limited, depending on how extensive digitization is (Arntz et al., 2017). The workplace plays a vital role in the well-being of individuals and must be considered when routine tasks are designed. In the Industry 4.0 context, a given worker assumes less responsibility, since he or she has less input into how production activities are actually carried out (Weyer et al., 2015). In this type of system, tasks are made more flexible to allow workers greater autonomy, which may become the primary objective of operational design (Gorecky et al., 2014). Digitization brings transformative changes, notably work at remote locations, including from home, thus making workplace relations virtual and reorganizing the physical workplace (Ben Aziza et al., 2021; Gomez, 2018; Treyer and Lau, 2018; CGI Group, 2017; 2016; Danjou et al., 2017).

In Quebec businesses, occupational health and safety has become a decisive criterion in project selection (Badri et al., 2012). Company directors systematically cite labor shortage as a major issue, and therefore strive continually to improve prevention and risk analysis and management. Although few studies have focused on the health and safety impact of technological transformations of the workplace, digitization undoubtedly affects worker health and safety at all scales of business in all sectors (Badri et al., 2018). The new ways of working allow employees to group together and pool their knowledge and expertise, and companies as a result reap gains in productivity (Gorecky et al., 2014). This degree of automation of production makes the industry as a whole behave more intelligently, and creating the new job of using the gathered data to predict demand (Moeuf, 2018).

3.7.1. The positive social impact

The positive impact of the digitization of small-to-medium-scale manufacturing operations can be summarized as follows (Badri et al., 2018; Jocelyn et al., 2017):

- Use of large volumes of data to analyze performance more thoroughly and accurately, predict errors more reliably, and manage risk more effectively.
- Use of robotics to decrease the physical burden on workers and reduce their exposure to workplace hazards.
- Use of the Internet of Things for remote monitoring and control of equipment, thus reducing the need for workers to enter cramped or hazardous spaces.
- Use of artificial intelligence to enable autonomous devices to identify risks and make decisions without delay.

- Use of simulations to predict risks and increase the likelihood of anticipating hazardous situations involving equipment or processes not yet in place.

3.7.2. The negative social impact

The principal negative effects of digital automation of manufacturing are unpredicted changes to equipment operator behavior and increased frequency of accidents as a result (Badri et al., 2018; Gosselin, 2005). This obviously decreases productivity and overall operational efficiency. The following effects in particular are noted:

- Improper use of equipment, affecting worker wellness and quality of life.
- Tendency of employers to neglect or suspend compliance with occupational health and safety legislation during and after the technological upgrade.
- Decreased direct interaction with machines and increased mental burden reduce awareness of or sensitivity to physical surroundings.
- Changes in lifestyle and habits leading workers to abandon community activities.

3.8. Economic impacts of digitization in the workplace

Automation and robotics have increased efficiency and productivity considerably and should continue to improve the profitability of manufacturing (Roubini and Mihm, 2010). Software development, engineering, scientific research and other professional activities are also expected to benefit from these technological advances as long as the required knowledge and skills are available. Digitization reflects the permanent integration of equipment and process interconnection into production operations and hence the transition of the manufacturing sector to Industry 4.0. The future impact of this revolution on the labor market is starting to appear in terms of the growing heterogeneity of industry and the variety of emerging types of jobs (Degryse, 2016). However, it is difficult to predict the future of specific industries and jobs therein. In general, the impact of digitization will be apparent also on the macroeconomic scale in terms of labor market developments (job elimination, creation and transformation by human-machine interfaces, relocation), the rise of digital platforms and crowdsourcing, the fallout from disruptive events (network crashes, cyber attacks), and job quality and pay scales (Degryse, 2016).

Some pessimism has been expressed by observers who are alarmed by the shift from manufacturing-based to service-based employment. They note that even before the end of the third industrial revolution, highly qualified workers in the manufacturing sector were being replaced by machines, and that future factories containing hundreds of machines could conceivably employ a single very knowledgeable engineer plus one handyman, and that even sweeping the floor would become the task of a robot (Roubini and Mihm, 2010). Under such conditions, salaries and jobs as millions of people currently conceive them could become fading memories (Brynjolfsson and McAfee, 2012). These

problems are plausible as long as industry does not experience any serious recession or stagnation and can therefore contemplate profound structural adjustments. Technology advances faster than the labor force can acquire the corresponding skills and knowledge (Badri et al., 2018). The key to avoiding dire social consequences will be to understand these transformations and their implications well enough to devise strategies that will allow workers to surpass the capabilities of machines rather than rely on their knowledge of machine functioning to remain employable (Badri et al., 2018; Brynjolfsson and McAfee, 2011).

In addition, legislators and the public sector must not become idle observers of digitization but must also adopt the new technologies. This is underway in Quebec, where the social and economic sectors of society are both the focus of developmental strategies designed to increase the growth potential of organizations (Gouvernement du Québec, 2019). The aim of these strategies is to accelerate the digital transformation of the Quebec ecosystem and thereby stimulate its economic development (Gamache et al., 2019). This type of initiative could become part of the global digital revolution. Strategic planning sets objectives and ensures their coherence and integration based on the economic model applicable to each sector of activity.

3.8.1. The positive economic impact

The positive impact of digitization can be summarized as follows (Gouvernement du Québec, 2019):

- Considerable improvement of efficiency and productivity
- Increased production capacities and capabilities
- Reduced direct and indirect costs
- Creation of new economic opportunities
- Survival and improved competitiveness.

3.8.2. Negative economic impact

The negative impact of digitization appears as developments described as follows (Gomez, 2018; Villani et al., 2018; OCDE, 2015):

- Economic and employment instability
- Job growth in fits and starts, socially disruptive
- Increased unemployment, income, and wealth disparities between countries
- Pressures on global demand, as SMEs assume increased risks
- Conversion of tasks into capital-intensive activities that decrease production

It must not be overlooked how much manufacturing was a pillar of modern economies. SMEs have employed a large portion of wage earners and have created much wealth for society overall. Although the manufacturing sector now faces daunting challenges in Western nations, the commercial

opportunities are also huge. Table 3 (adapted from Arlandis et al., 2011) summarizes the opportunities and the threats on the horizon for SMEs facing the prospect of digitization of their business.

Insert Table 3 here

3.9. Challenges facing SMEs in a digitized world

Several aspects of digitization are related to business strategy (Vivier and Ducrey, 2019), particularly company vision and leadership, organizational culture, technology and data management, follow-up parameters, and so on. Leadership and the direction in which business development heads are practically indissociable. The aim of technological management is to meet business objectives while solving problems related to cyber security and the use of technologies. Data management concerns all aspects of data storage, processing, and quality control. Organizational culture determines how skills are utilized and hence how processes are transformed successfully to their digital versions. Follow-up indicators support decision-making, using reliable data.

Five years ago, only 22% of Quebec SMEs in the manufacturing sector had begun to plan their transition to digital control (CEFRIQ, 2017). In the rest of Canada, this transition was underway in 39% of such businesses, although only 3% had digitized their production processes completely, 17% were in the planning stage, and 42% had not adopted any measure. Not long after, most small manufacturing companies appeared unprepared to get on board with the Fourth Industrial Revolution (Gamache et al, 2019). The results of several studies of the Quebec SME value chain indicated that less than one third of the companies surveyed were using integrated management or customer relations management software to gather and process data and support decision-making (Gamache et al., 2019). This study also revealed a lack of data management and of appropriate tools for planning, production, and manufacturing facility configuration. In all cases, digitization would have provided opportunities to improve processes and increase the efficiency, flexibility, and agility of operations, which raises questions about how motivated the managers were to remain competitive.

Lack of knowledge, resources and vision appear to underlie the persistent inability of SMEs to build and maintain a digital environment competitive enough to increase exports (Sommer, 2015). Some directors of such companies apparently remain unconvinced of the enormous potential that digitization represents for their business. Meanwhile, strategic organizations are emerging with technological tools adapted to their needs, and companies that do not get on board risk being left far behind. The assets that accrue from joining the SME migration towards Industry 4.0 have been described as follows (CGI Group, 2017):

- Digitization self-propagates throughout the value chain of an SME
- The main operational factors are cost reduction, increased flexibility, and shorter delays in the commercialization of new products

- Digitization enables IoT solutions and Cloud mobility
- Upgrades of existing information technologies and computerized systems not only support but make up a key element of digitization.

3.10. Criteria and indicators of evaluation of the socioeconomic impact of digitization

An element of reference that can be used to judge, appreciate, or define something or build a judgment is called a criterion. A criterion is based on a set of indicators that collectively describe a state. Economic indicators include employment, production, personal income and so on. Commonly used social indicators include social cohesion, occupational health and safety, quality of life, investment in the local community and so on.

Indicators can be used to measure economic and even macroeconomic activity. In the industrial context, indicators of overall equipment effectiveness or overall operational yield are frequently used. To be valid and effective as a measurement of the impact of something, an indicator must be chosen carefully: it should itself be measurable precisely, objectively, and reliably over time (Spangenberg, 2002). The difference between a criterion and an indicator is that the former expresses the importance of the need to evaluate, whereas the latter provides the information needed to determine if the criterion is met.

The use of criteria and indicators plays the same role in ensuring the success of digitization as it does in any other investment project. Identification and application of a limited number of suitable indicators are often weak in SMEs (Treyer and Lau, 2018). Simple generic indicators that are easy to use are tempting but might not be the most relevant, that is, yield data that can be cross-referenced or that reveal what needs to be improved in a business. In any project of which sustainability is a goal, the relationship between the indicators and the criteria of evaluation of success must be clear. In all fields so far found relevant to sustainability, digitization represents considerable added value and hence motivation to use the latest technological advances. In SMEs, multiple criteria and suitably adapted indicators will be necessary to provide the understanding needed to devise new systems that are both innovative and responsible. Scientific articles and case studies are helpful for guiding this choice. Following the establishment of the proper criteria and indicators, the economic or social impact of any action can be evaluated.

The fields in which the impact of digitization has been studied are summarized in Table 4.

Insert Table 4 here

Some of the criteria and indicators found most relevant are listed in Table 5 (social impact) and Table 6 (economic). Social indicators are expected to reveal and if possible, measure some impact (desired or otherwise) of digitization on workers and organizations. Equipment upgrades and improvements of

shop floor managerial methods resulting from digitization can have a significant impact on worker health and safety, especially by reducing the risk of accidents in the workplace (indicators A1 and A2). The number of accidents avoided after the digitization project can be estimated directly (indicator B1). Improvements to the supply and demand dynamics of training, awareness-raising seminars, acquisition of new skills, and the acceptance of new practices designed to maintain a healthy work environment must also be evaluated (indicators A3, A4 and A5), as well as the number of persons concerned (indicators B2 and B3). The direct impact on production methods (indicator A6), and on the consumption and modes of exchange of the goods and services produced (indicator A7) are both measurable. The latter allows evaluation of the number of digital devices used to complete the tools of production (indicator B4) and provides a measurement of goods and services efficiency (indicator B5). The possible impact of automation on human-robot interactions can be estimated (indicator A8). Digitization can represent new opportunities for human development in addition to industrial technical capability (indicators A9, A10), in particular by decreasing the number of risk factors or hazards before installing in the workplace robots intended to utilize these interactions (indicator B6).

Indicators used to measure the economic impact of a digitization project focus generally on two dimensions: job transformation and creation, and economic growth (OCDE, 2015). The literature on the economic impact is more abundant, and economic indicators are viewed as indispensable, since they provide the most compelling arguments to convince managers.

The impact on employment can be expressed qualitatively or quantitatively (Table 6), as the number of persons employed or the number of jobs mobilized as a result of implementing digitization (C1, D1 and D2). Creation of skills (D3) is another useful indicator. Research and development includes creative work and should be counted as an increase in worker skill (OCDE, 2015). It also includes knowledge transfer and application of new methods through experimental development, applied research and even basic research. Knowledge is thus acquired through research or practical experience. All of these activities lead to new product launches as well as new or improved processes.

Quebec has seen cases of rapid adoption of successful innovations (indicator C3) in the realm of digitization (Gomez, 2018) as well as robotic adaptation (C4) and even improved productivity and accounting of failures (D4 and D5). Digitization has upgraded the economic structure not only in terms of collaboration between businesses but also economic governance (C5 and C6). This appears not only as increased sales for individual companies but also as growth in GDP (D6, D7 and D8). The benefits of practices that are more environmentally friendly, based on workplace efficiency, provide an additional argument in favor of the transition to digitization (C7 and D9). For example, modified work methods,

technological choices and proper servicing and calibration of equipment and machinery can bring non-negligible increases in resources use efficiency.

Insert Table 5 here

Insert Table 6 here

3.11. Results of the survey of Quebec SMEs

The developed questionnaire is intended for project managers involved in digital transformation within manufacturing SMEs in Quebec. The Quebec manufacturing sector is highly diversified, ranging from aerospace, metallurgy, and wood processing to agri-food, pharmaceuticals, and clean technologies.

Based on a database containing contact information for over 350 Quebec companies operating in various industries, 230 of them were identified as manufacturing firms.

Ultimately, only 34 out of the 230 contacted companies completed the questionnaire correctly. This low response rate may be explained by the health context related to COVID-19.

As validation of the theory, the results of a survey conducted among a sample of supervisors and project managers in 34 Quebec SMEs are presented and analyzed below.

These results consist of the responses to a questionnaire sent by email after discussion by phone and agreement of the participants. Written comments were noted.

3.11.1. Portrait of the SMEs surveyed

The work experience of the respondents was distributed as follows: 36% had 1 to 2 years, 26% had 2 to 5 years, 18% had 5 to 10 years, and 21% had more than 10 years. The size distribution of the companies is shown in Table 7.

Insert Table 7 here

Most of these companies (77%) were not applying any organized approach to transitioning to Industry 4.0. The remainder (23%) claimed to be in the process of digitizing (Fig. 3). These results are consistent with previous findings that only 22% of Quebec SMEs had begun the transition (CEFRIO, 2017).

Insert Fig. 3 here

Most of the companies have some experience with digitization projects. As shown in Fig. 4, 32% have at least one project started, 16% are planning a project, most (50%) are in the execution phase, and 2% have completed their projects.

Insert Fig. 4 here

The two digital technologies best known and used by the managers are simulators and the Internet of things, at respectively 75% and 23%. Big data is used in 15% of the companies, whereas only 9% are

proficient with tools of artificial intelligence. In contrast, cyber-physical systems appear to be unknown in this group of respondents (Fig. 5).

Insert Fig. 5 here

3.11.2. General impact of digitization in the SMEs

a) Digitization as a source of opportunities

Regarding attitudes or beliefs (Fig. 6), 26% of managers agreed entirely and 38% agreed at least somewhat that digitization represents a source of opportunity for their business, 29% had no opinion, whereas 3% disagreed somewhat and 4% disagreed entirely.

Insert Fig. 6 here

b) Ease of use of digital technologies

The respondents were mostly project managers, a position that normally requires being relatively at ease with the use of digital technologies. This was the case of almost all the respondents (Figure 7). Moreover, the digitization project itself allowed managers to become familiar with tools such as simulators (51%), IoT (23%) and Big data (15%).

Insert Fig. 7 here

c) Perception of risks associated with digitization

Many managers (38%) disagreed that digitization represents a risk to the company, whereas 33% believed that it carries some risk (Fig. 8).

Insert Fig. 8 here

d) Level of advancement in the use of digital technologies

The answers to the questions relating to the perceived level of digital technology use reveal that 25% of respondents disagreed that their company was advanced in this respect. A smaller fraction (8%) had no clear opinion, and 67% agreed, implying that they believed their companies to be adopting digital technologies at a satisfactory pace (Fig. 9).

Insert Fig. 9 here

e) Optimism regarding digitization

More managers (46%) are optimistic about the effects of digitization on their company's future performance than about the future of their employees (27%) or about the future of their own jobs (27%). Opinions on the consequences of increased utilization of digital technologies are summarized in Fig. 10.

Insert Fig. 10 here

f) Improvements expected to accrue from digitization

Productivity was the factor most expected to improve in the SMEs surveyed (by 28% of respondents), followed by employee autonomy (21%), innovative spirit (15%), and economic competitiveness (15%).

Only 12% of respondents believe that digitization will reduce stress in the workplace, while 10% anticipate an improvement in the quality of working life (Fig. 11).

Insert Fig. 11 here

g) Occupational health and safety risks associated with digitization

More and more businesses are paying closer attention to situations that could pose threats to the safety and health of their workers. In Quebec SMEs, 94% of the respondents to our survey are preoccupied with occupational risks that could arise from the use of Industry 4.0 technologies, and they accordingly anticipate adopting safe work methods (Fig. 12).

Insert Fig. 12 here

h) Overall satisfaction with digitization

Nearly half (46%) of managers of Quebec SMEs express neither satisfaction nor dissatisfaction with their company's transition to Industry 4.0, while 42% are satisfied, 9% are less than satisfied, and 3% are not at all satisfied (Fig. 13).

Insert Fig. 13 here

3.11.3. Level of impact of digitization

a) Impact on the development of technological skills

Fig. 14 shows how significant an effect digitizing company operations has had on the technological skills of employees of Quebec SMEs, as perceived by the respondents. Only 4% indicated that the impact was deeply felt, while 23% considered it significant, 30% said moderate, 30% said weak, and 13% believed that it had no impact.

Insert Fig. 14 here

b) Impact on work methods

Fig. 15 shows the extent to which digitization changes work methods, as perceived by managers of Quebec SMEs. About 40% of the respondents indicated that the impact on work methods was moderate, while 30% felt that it was significant, 17% considered it to be weak, and only 7% viewed it as profound, with 6% finding it non-existent.

Insert Fig. 15 here

c) Impact on the future of certain jobs

Fig. 16 shows how the respondents viewed the impact of digitization of their operations on the future relevance of certain workplace tasks and the possibility of some jobs disappearing. A surprising 67% did not anticipate any such impact, 20% expected a weak impact, 10% a moderate impact and 3% a very profound impact on jobs.

Insert Fig. 16 here

d) Impact on employment

The impact of digitization on unemployment, as perceived by managers of Quebec SMEs, is shown in Fig. 17. Again, 67% of the respondents do not anticipate any impact. About 27% expect a weak impact and 7% a significant impact.

Insert Fig. 17 here

e) Creation of new economic opportunities

The creation of new economic opportunities is one of the more important themes in the literature on the consequences of digitizing the workplace. However, 40% of the respondents to our survey do not expect any such impact of their technological upgrades to digital and 37% expect a weak impact (Fig. 18). Only 23% anticipate a moderate or greater impact.

Insert Fig. 18 here

f) Impact on the utilization of machines and robots

Upgrading of equipment and operations to all-digital technologies logically should open the door to expanded use of programmable machines and robots. Among the respondents to our survey, 40% expect the use of machines and robots to increase significantly at least. The remainder expect moderate to no impact of digitization on this type of investment (Fig. 19).

Insert Fig. 19 here

a) Impact on compliance with occupational health and safety legislation

Managers of SMEs in Quebec generally do not expect the digitization of shop-floor operations to affect their commitment to complying with occupational health and safety legislation. Only 7% express the opinion that this investment will have a significant or profound impact on this aspect of life in the workplace (Fig. 20).

Insert Fig. 20 here

4. Discussion

The transition to digital control and monitoring of manufacturing processes and business operations is viewed as a reality by 23% of managers of Quebec SMEs. These persons are proficient in all Industry 4.0 technologies except cyber-physical systems. A larger percentage (32%) believes that the risks associated with this change are not negligible. Based on the responses, digitization appears to have been an effective investment for increasing productivity in 27% of the businesses surveyed, while 42% of managers say they are satisfied with the transformation. A slightly higher proportion (46%) is optimistic about the future of their business, while an alarming 94% remain preoccupied with occupational health and safety concerns.

Some socioeconomic impact has been noted already or is expected, for example, development of new skills among production staff (according to 86% of respondents). In addition, 94% of managers expect substantial modification of work methods, yet only 33% anticipate the disappearance of some jobs,

while 60% see new economic opportunities, 80% expect to see greater use of machines and robots, and 40% expect these changes to affect the daily lives of employees.

4.1. Different criteria and indicators will be needed to evaluate the sustainability of digitized SMEs

Sustainable development is an action or process whereby current needs are met without compromising the capacity of future generations to meet their needs, based on criteria relating to the environment, the economy, and society. Business decisions must take into consideration the impact on these three spheres, on the short term and into the future as far as this is feasible. The choice of organizational and operational strategies must do likewise. However, from a sustainable development perspective, SMEs can use multiple indicators to guide their digitization projects. These criteria or indicators are listed above under social and economic dimensions (Tables 4 and 6). The social dimension groups criteria such as occupational health and safety, workplace management, automation of industrial processes and human-robot cohabitation, all of which can be affected by a digitization project (Table 5). The economic dimension includes criteria such as job transformation and creation, innovation, growth of the economy, and the efficiency and effectiveness of resource utilization. It is in this dimension that the impact of digitization is expected to be mostly positive. The sustainability of SMEs will depend on their work methods and on their technological upgrades respecting these and possibly other socioeconomic criteria.

4.2. Digitization as a source of opportunity for SMEs, with economic and social impact

Upgrading to all-digital instrumentation is a major strategic asset for SMEs. By integrating digital technologies, it becomes possible to generate and manage large amounts of data and related services. Information gathering, transmission, processing and sharing in real time enhance business acumen. The economic value of timely, rational, and informed decision-making must not be underestimated. This increases the potential for innovative SMEs to become large businesses.

However, digitization is not without drawbacks, both at the creation and in the operation of SMEs. This transformation is based on the integration of technologies that are complex to implement, use and maintain. Highly specific skills are needed, which demand re-examining company staffing in terms of employee numbers, organization, and trainability.

The impact of digitization on industrial businesses has been the focus of various studies. For the purposes of the present research, we collected and processed a variety of indicators, namely new job creation, development of skills by workers, modification of work methods, job obsolescence, recent increases in unemployment, creation of new economic opportunities, and so on. The results of this study suggest that digitization of SMEs will have a socioeconomic impact estimated as weak to moderate. We therefore may conclude that the transition to Industry 4.0 constitutes a source of opportunity of SMEs and that the impact of digitization of the workplace will be socially and

economically positive overall.

4.3. Policy and managerial recommendations to support the digital transformation of SMEs

To effectively support the digital transformation of manufacturing SMEs, it is essential to align and strengthen both public policies and managerial strategies.

4.3.1. Policy recommendations

- Targeted financing programs: Governments should implement specific financing programs, such as tax credits, innovation grants, or low-interest loans, to reduce the financial barriers to adopting Industry 4.0 technologies for SMEs.
- Investment in digital innovation centers: Public investments in regional digital innovation centers can provide SMEs with access to digital technologies, expertise, and collaborative opportunities. These centers can act as hubs for digital learning and prototyping, assisting small manufacturers in building necessary skills and capabilities.
- Digital education and training programs: Governments should invest in digital education and training initiatives that target both SME managers and employees, providing them with the skills to navigate and implement digital technologies.

4.3.2. Managerial recommendations

- Building a digital culture: SME managers must prioritize the development of a digital-first culture, fostering openness to new technologies and continuous learning. This includes encouraging staff at all levels to embrace change and be proactive in adopting digital tools.
- Partnerships with technology providers: SMEs should seek partnerships with technology vendors, digital consultants, and innovation ecosystems to access external expertise and resources that can support the seamless integration of digital solutions.
- Incremental approach to digitalization: Given the resource constraints of SMEs, adopting a phased and incremental approach to digitalization is recommended. This approach allows for testing and scaling technologies gradually, ensuring alignment with business goals and minimizing risk.

These policies and managerial strategies, when implemented together, can help overcome the challenges that SMEs face in adopting digital technologies and ensure that they remain competitive in the digital economy.

4.4. Limitations of this research

The limitations of this study arise primarily from constraints related to the representativeness of the sample and the robustness of the statistical methods used, which in turn affect the generalizability of the results. One limitation is the uncertainty surrounding sample representativeness. Since the SMEs

that agreed to participate may have been atypical, with many businesses declining our invitation or appearing distrustful despite reassurances of confidentiality, the sample may not accurately reflect the broader population of SMEs. Another limitation arises from the use of MS Excel® rather than SPSS® for data processing, which may have impacted the robustness of the statistical analysis. Additionally, the use of a questionnaire with such a small sample size poses another limitation, as extending the interpretation of the results to other contexts could be risky without verification in the field.

Another important limitation of this study is its exclusive focus on SMEs in Quebec. This geographic limitation may not account for the varied challenges and opportunities faced by SMEs in different provinces or countries. As such, the findings may not be fully generalizable to other regions or industries with distinct economic, cultural, or technological contexts.

Moreover, the study primarily focuses on the short-term impacts of digitalization, while the long-term effects on sustainability and business performance remain unexplored. Future research could benefit from examining the longitudinal impacts of digital transformation across a wider range of SMEs in diverse provinces or countries, which would enhance the generalizability of the findings.

A promising future research direction would be to conduct a longitudinal study to assess the long-term economic and sustainability impacts of digitization on SMEs. Unlike cross-sectional data, longitudinal data allows for the tracking of changes and developments over time, providing deeper insights into how digital transformation influences organizational performance, resource efficiency, and sustainable practices. Such an approach would offer a more comprehensive understanding of the dynamic nature of digitization and its evolving implications, both positive and negative on SMEs.

The chapter primarily addresses the social and economic dimensions of sustainable development. While the environmental aspect of sustainability is indeed important, the research team did not possess the specific expertise or analytical tools required to explore this dimension in depth. As such, the study focused on areas where meaningful and accurate insights could be provided, while recognizing the need for future interdisciplinary collaborations to fully address the environmental implications of digitalization within the framework of Industry 4.0.

For brevity, some results were not presented in detail. However, the raw data will be available to researchers in accordance with editorial policy and through the authors' ResearchGate accounts. Additionally, this type of study could be expanded in the future to include a substantially larger number of businesses and utilize more sophisticated statistical analysis tools to confirm the validity and generalizability of the results.

5. Conclusion

Upgrading of technical means to digital monitoring and control of manufacturing and business processes holds enormous potential for the development of SMEs in the manufacturing sector of the

Quebec economy. However, this transition raises questions about sustainability. From a socioeconomic perspective, this type of SME must find means of reducing the immediate impact of the integration of the technologies adopted, by devising new managerial methods and cultivating novel relationships with the various stakeholders.

The primary goal of this study is to raise awareness among SMEs about the importance of digital transformation and its potential impacts on sustainability and long-term performance. Given the focus on sensitizing business owners and managers, a descriptive approach was chosen to provide a clear and accessible overview of the current state of digitalization within Quebec SMEs. While more robust statistical techniques could certainly provide stronger causal inferences, the aim of the study is to engage SMEs in a practical, non-technical manner, encouraging them to take the digitalization process seriously. The descriptive findings are intended to offer valuable insights and serve as a foundation for future research with more advanced methods.

This research has allowed us to highlight elements of digitization that have at least some socioeconomic impact and implications for sustainable development and to identify suitable criteria and indicators for the evaluation of sustainability in the SME context. This was based mainly on the review of the literature. The survey of Quebec SMEs provided some confirmation, showing that digitization in this setting could have socioeconomic impact estimated as weak to moderate. In conclusion, digitization of information-based operations constitutes a source of opportunity for SMEs in Quebec's manufacturing sector and may be expected to have an overall positive social and economic impact.

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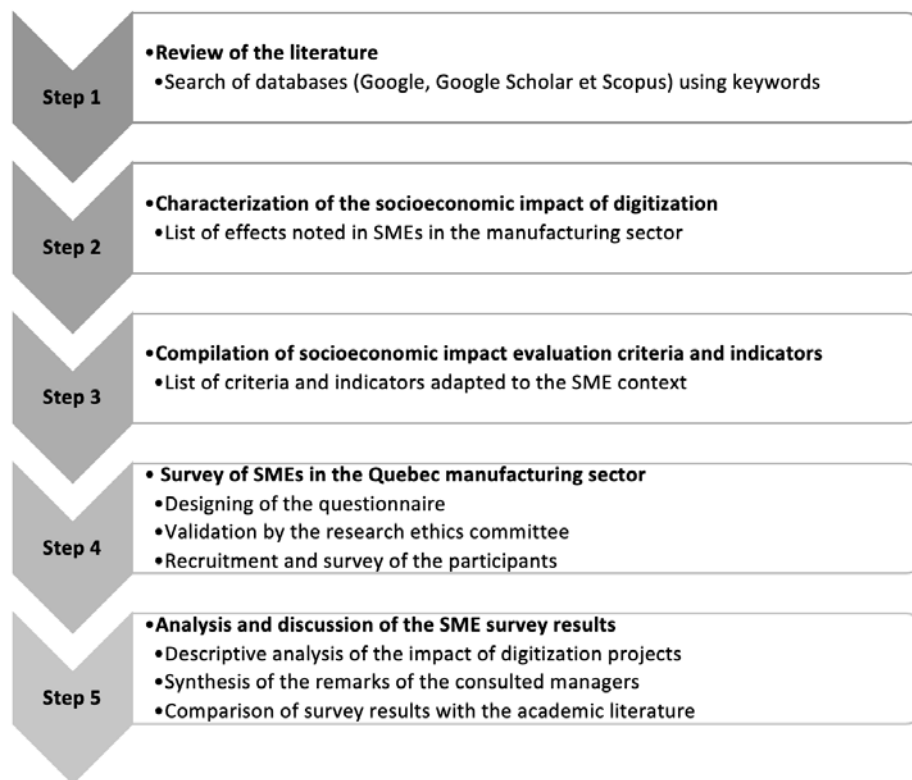


Fig. 1 Chronological description of the research methodology. Source: Authors' own elaboration (from the research data)



Fig. 1 Issues of special concern raised by Industry 4.0. Source: Authors' own elaboration (from the research data)

Table 1 Technological tools used to upgrade manufacturing operations to Industry 4.0. Source: Authors' own elaboration (from the research data)

Tool category and areas of application		Description
Product and process design	Simulation	Use of computerized modeling to represent industrial process behavior, to teach future workers and technicians and familiarize them with complex work tools.
Piloting and control	Big data	Use of datasets of sizes and complexities beyond the analytical capabilities of the human mind, and of database management software to extract meaningful and useful information therefrom
	Internet of Things	A standardized and unified electronic identification system composed of mobile wireless networks, digital entities and physical objects that collectively gather, store, transmit and process an uninterrupted stream of information between the physical and virtual worlds.
Manufacturing operations	Artificial intelligence	Technologies designed collectively to allow machines to imitate human capabilities of evaluating and choosing among possible responses. Current fields of applications are numerous and growing in number.
	Cobotics	Close cooperation between humans and robots to achieve an objective.
Services	Cyber-physical systems	Systems in which informatic elements (algorithms, databases) collaborate to control physical entities.

Table 2 Advantages of applying the principles of sustainable development to an SME digitization project. Source: Authors' own elaboration (from the research data)

Advantages associated with human resources	Economic advantages	Strategic advantages
- Improved quality of the work environment - More attractive to workers - Better retention of staff - Improved productivity	- Reduced costs of operation and utilization of resources - Improved financial performance - Improved access to financing, strategic funding	- Improves corporate image - Stimulates innovation - Improves customer loyalty - Consolidates market share - Improves access to markets - Strengthens relationships with commercial partners - Improves risk management

Table 3 Opportunities and threats associated with digitization of operations in SMEs. Source: Authors' own elaboration (from the research data)

Opportunities	Threats
- Connected world and growth economy - Networks, exchanges, data sharing, collaboration - Integration of industries (intelligent factories and systems) - Automation, robotics - Increased productivity - Innovation, new products - New jobs (network experts, engineers, software designers, etc.) - More flexible and autonomous jobs - Elimination of repetitive routine tasks - Fewer heavy and complex tasks - Collaboration and cooperation between machines - Reduced working hours	- Uncoupling of economic growth from employment growth - Non-compliance with regulatory, social, and administrative standards - Theft or misuse of personal information - Automation of work habits: increased constraints on individuality - Massive elimination of jobs that do not require higher education - Weakening of collective bargaining strength and industrial relations - Disconnect between education/training and job qualifications - Stagnation or loss of personal income

Table 4 Fields of study relevant to the impact of workplace transformations. Source: Authors' own elaboration (from the research data)

Dimension	Field of study
Social	- Occupational health and safety - Workplace management - Automation of industry - Human-robot cohabitation
Economic	- Transformation and job creation - Innovation - Economic growth - Efficiency and effectiveness of resource use

Table 5 Indicators of the social impact of investment projects. Source: Authors' own elaboration (from the research data)

Criterion	Indicator	Example	Reference	Subject area
Health and safety	A1: Worker safety conditions improved A2: OHS record improved	B1: Number of major accidents avoided (based on past performance)	ISO (2015); Jocelyn et al. (2017)	Risk management, control
Management of the work environment	A3: Supply and demand for training and awareness raising (improved) A4: Acquisition of skills A5: Acceptance of new practices to improve workplace safety and quality (improvement of)	B2: Number of participants in seminars or other training B3: Number of cases of non-compliance with preventive measures, number of fines	Jocelyn et al. (2017)	Development of sustainable new workplace practices
Automation of industry	A6: Improvement of production methods A7: Improvement of consumption and modes of exchange of goods or services	B4: Number of digital devices used to complete the tools of production B5: Efficiency	Jocelyn et al. (2017); Greenan (1999)	New, more flexible approaches
Human-robot cohabitation	A8: Progress in industrial robotics A9: Opportunities for development, human adaptation A10: Technical development of the industry	B6: Number of risk factors before and after installing collaborative robots in the workplace	Martinez (2018); Burlet-Vienney et al. (2015); Jocelyn et al. (2017)	Extent of human adaptation, robot developed

Table 6 Indicators of the social impact of digitization projects. Source: Authors' own elaboration (from the research data)

Criterion	Indicator	Example	Reference	Subject area
Job transformation and creation	C1: Automation and creation of new jobs C2: Progression of digitization	D1: Number of employees D2: Number of jobs mobilized D3: Skills created	OCDE (2015). Villani et al. (2018); Brynjolfsson et McAfee (2011)	Acquisition of digital age expertise
Innovation	C3: Acceleration of ecosystem maturation C4: Growth of adaptation capacity with robotics	D4: Increases in production D5: Failures recorded	Gomez (2018)	Innovation at the heart of ongoing activity
Economic structure	C5: Inter-business collaboration (increase in) C6: Specific economic governance	D6: De-centralizing of production D7: Growth in sales D8: Growth of GDP	Arlandis et al. (2011) ; Gouvernement du Québec (2019)	Supporting rapid and sustainable development of the business
Efficiency of resource use	C7: Practices harmonized, economical and less harmful to the environment	D9: Efficiency	Gouvernement du Québec (2019)	Control of socioeconomic risks

Table 7 Number of employees in the businesses surveyed. Source: Authors' own elaboration (from the research data)

Number of employees	Percentage
Less than 50	54
50 to 99	23
100 to 299	13
300 to 499	10
Total	100

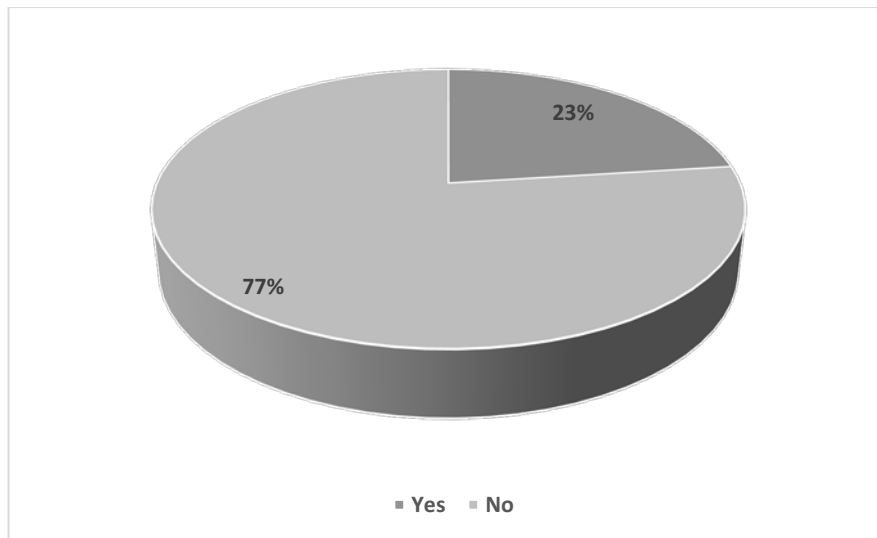


Fig. 2 Application of an Industry 4.0 approach in Quebec SMEs. Source: Authors' own elaboration (from the research data)

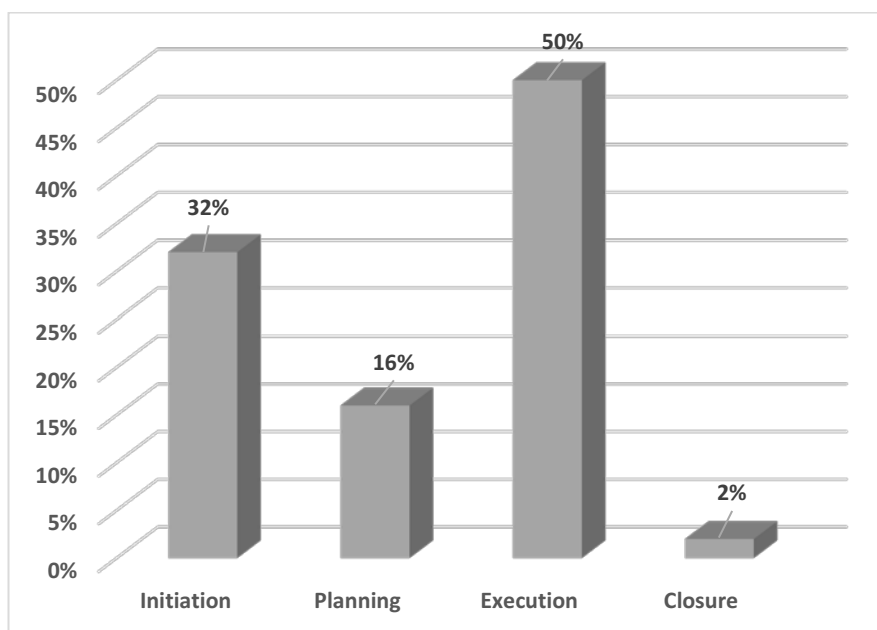


Fig. 3 Phase reached in digitization projects in Quebec SMEs. Source: Authors' own elaboration (from the research data)

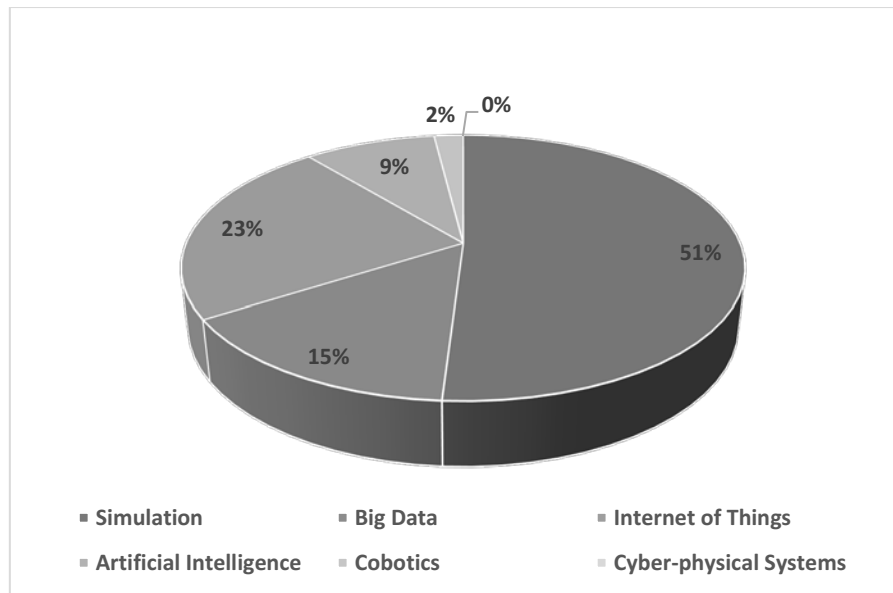


Fig. 4 Knowledge of and proficiency with Industry 4.0 tools in Quebec SMEs. Source: Authors' own elaboration (from the research data)

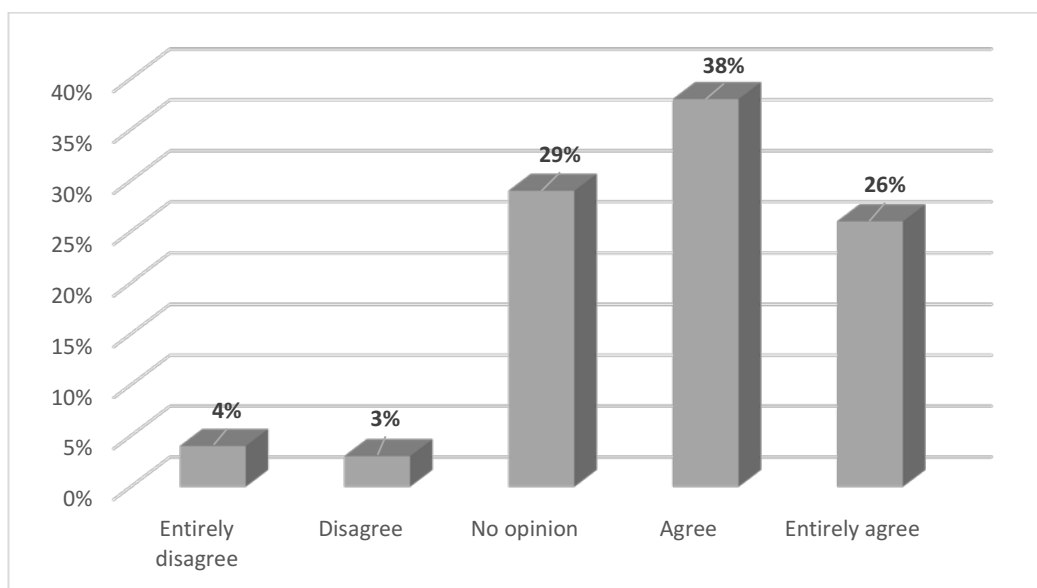


Fig. 5 Perception of the opportunity inherent in digitization in Quebec SMEs. Source: Authors' own elaboration (from the research data)

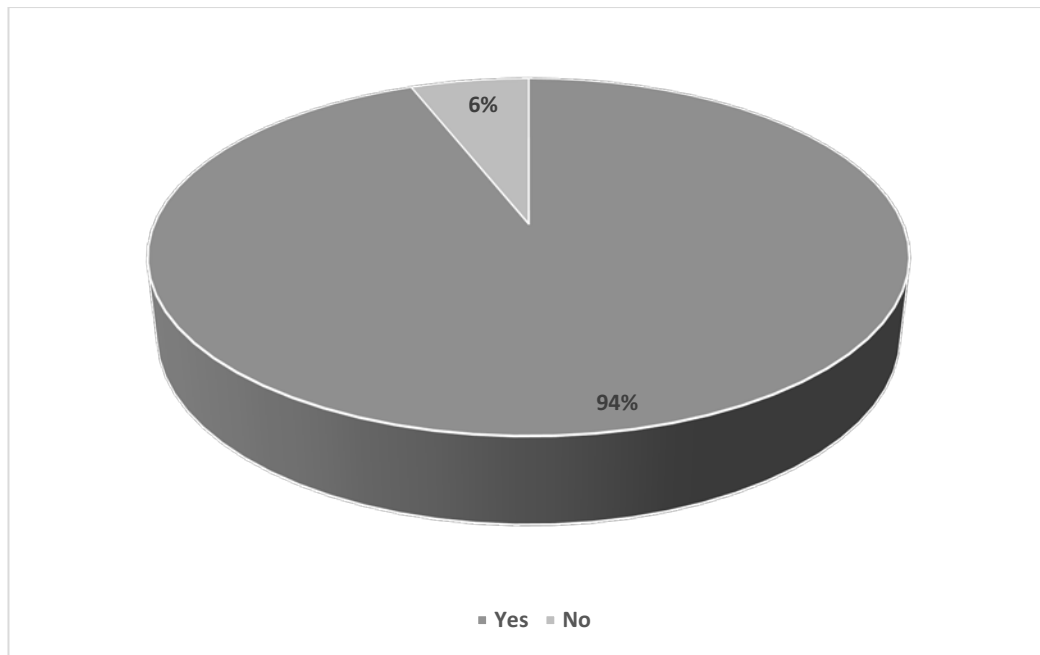


Fig. 6 Usage of digital technologies among managers of Quebec SMEs. Source: Authors' own elaboration (from the research data)

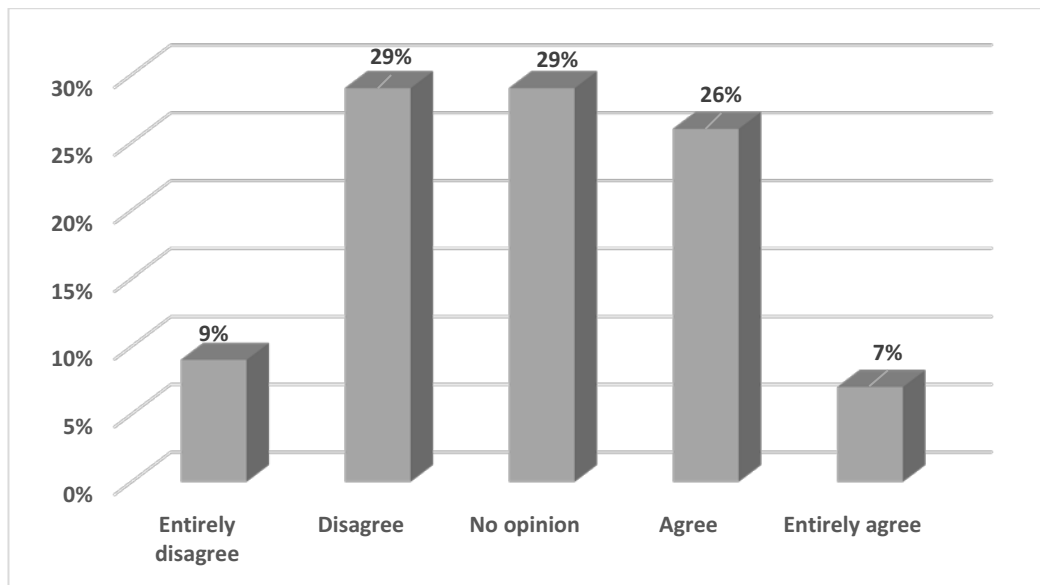


Fig. 7 Belief among managers of Quebec SMEs that digitization of business operations carries some risk. Source: Authors' own elaboration (from the research data)

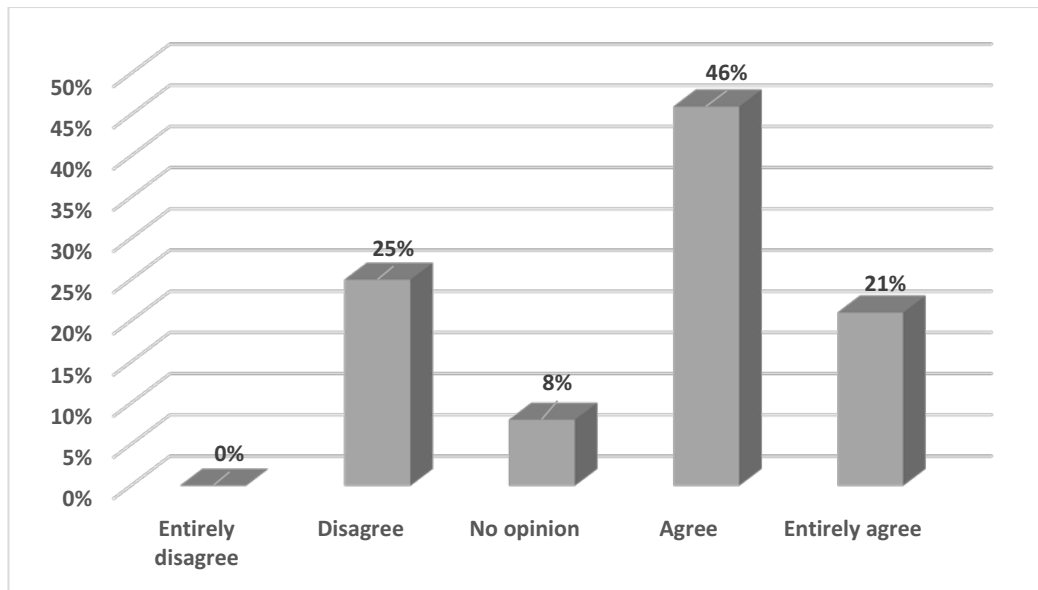


Fig. 8 Perception by managers of Quebec SMEs that the company is advanced in its use of digital technologies. Source: Authors' own elaboration (from the research data)

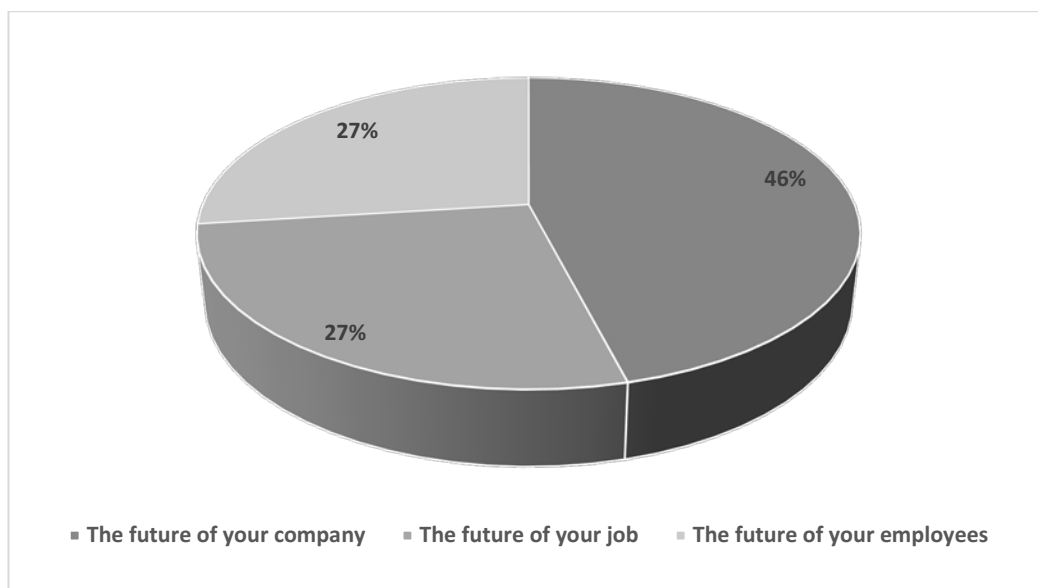


Fig. 9 Optimism of managers regarding the expected consequences of increased use of digital technologies in Quebec SMEs. Source: Authors' own elaboration (from the research data)



Fig. 10 Improvements that managers of Quebec SMEs expect following digitization of company operations and the workplace. Source: Authors' own elaboration (from the research data)

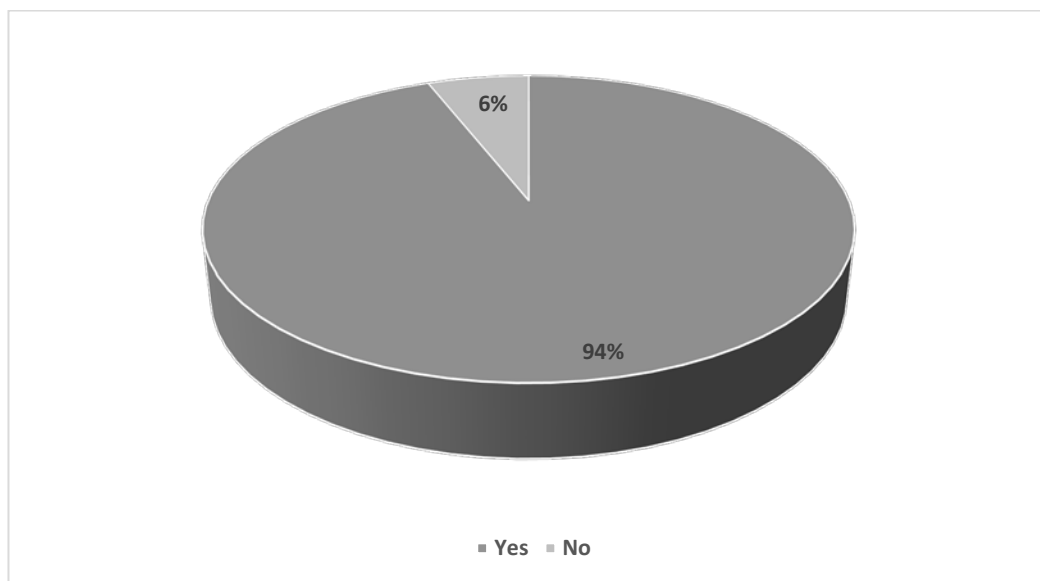


Fig. 11 Managers of Quebec SMEs who believe that the transition to Industry 4.0 carries risks for workers. Source: Authors' own elaboration (from the research data)

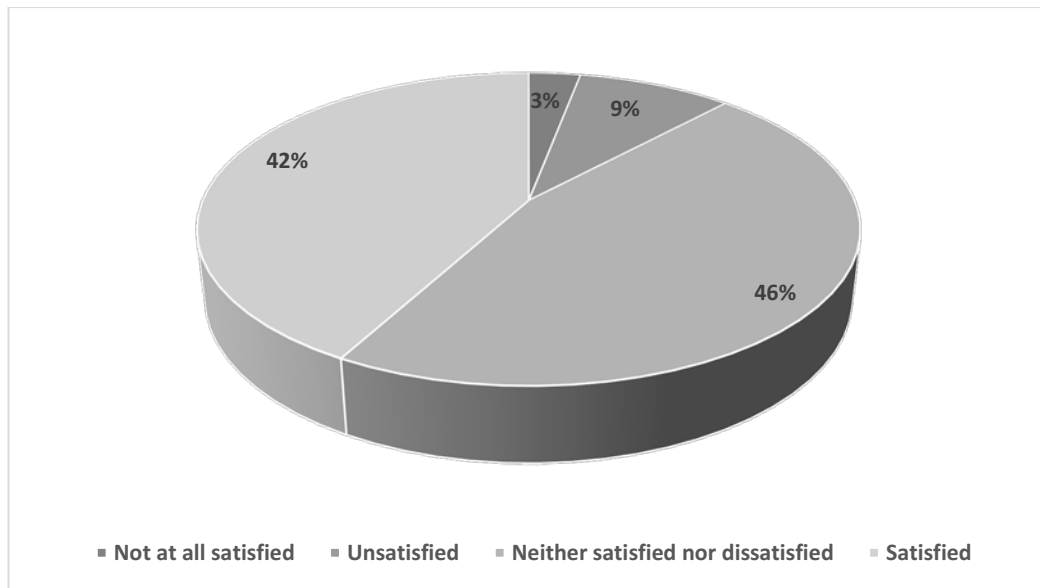


Fig. 12 Satisfaction expressed by managers of Quebec SMEs with their company's transition to digital technologies. Source: Authors' own elaboration (from the research data)

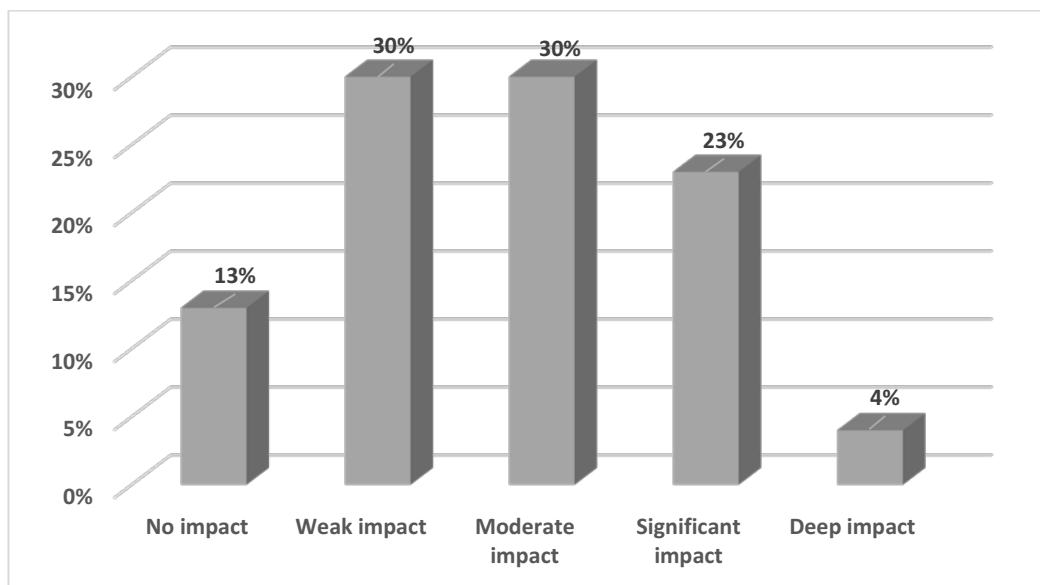


Fig. 13 Development of technological skills among staff in Quebec SMEs digitizing their operations, as perceived by managers. Source: Authors' own elaboration (from the research data)

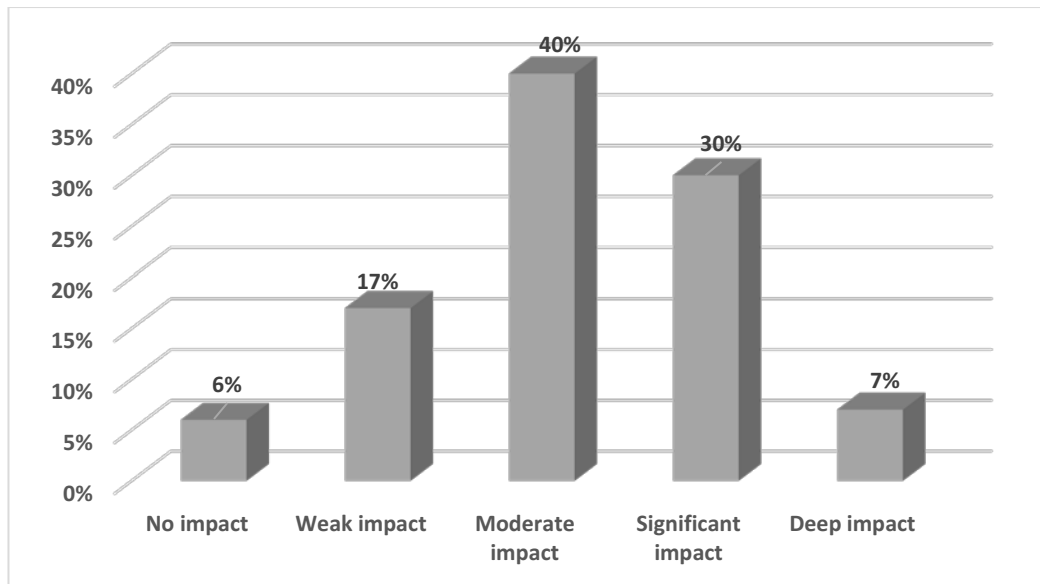


Fig. 14 Perceived impact of digitization on work methods. Source: Authors' own elaboration (from the research data)

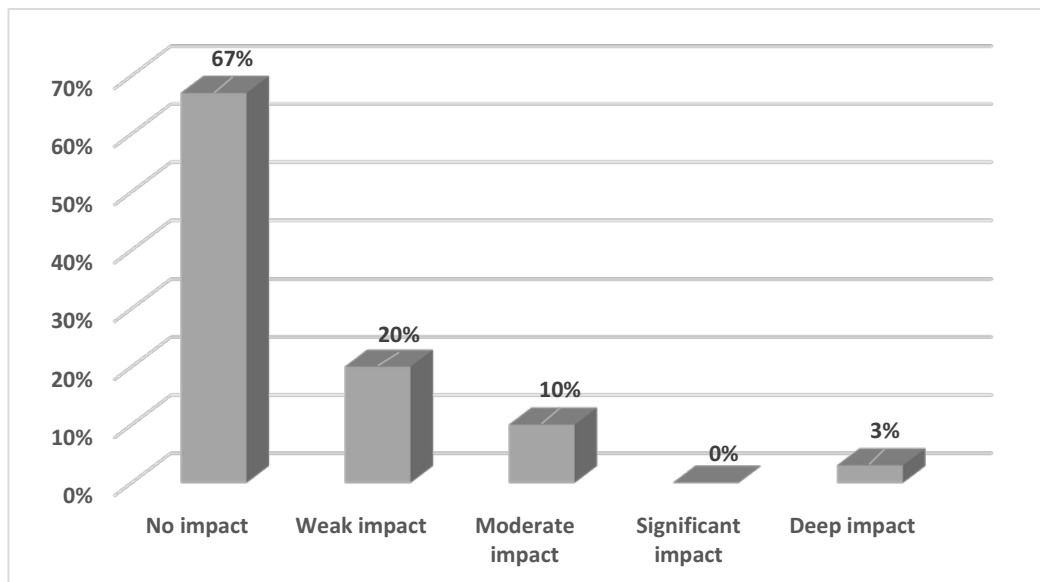


Fig. 15 Impact of digitization on the future of some jobs in Quebec SMEs, as viewed by managers. Source: Authors' own elaboration (from the research data)

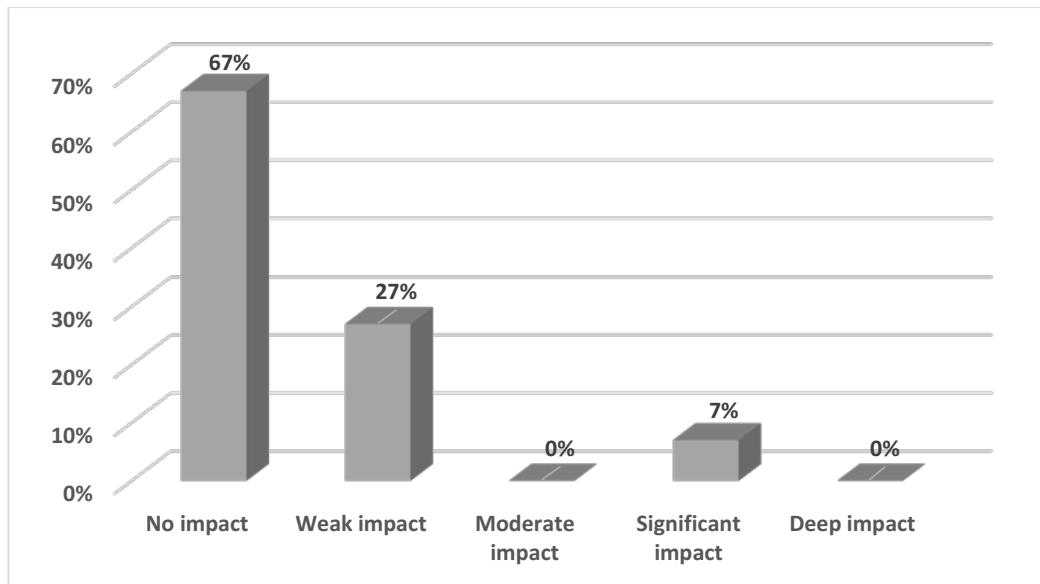


Fig. 16 Impact of digitization on future unemployment. Source: Authors' own elaboration (from the research data)

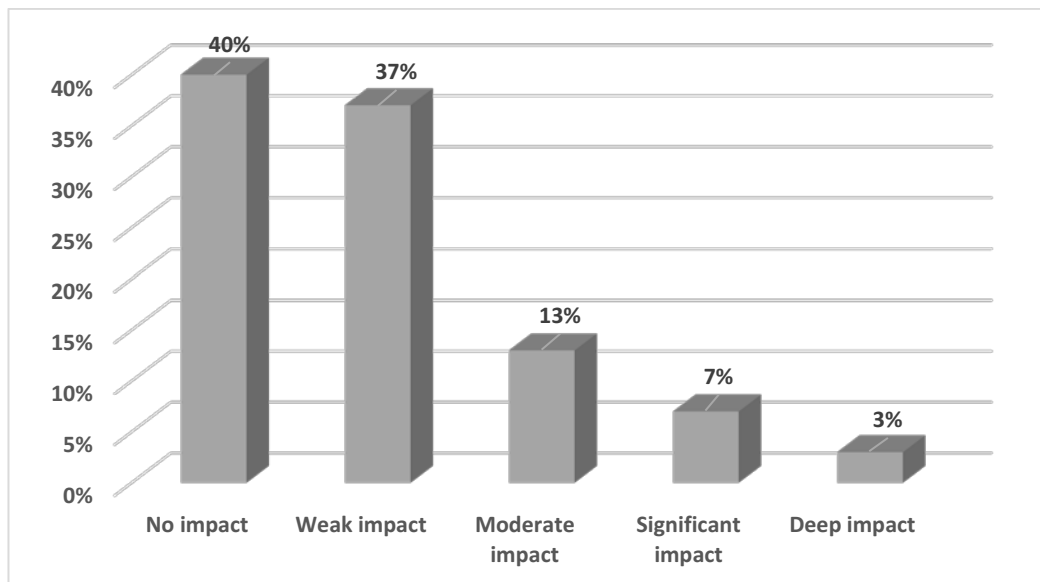


Fig. 17 Contribution of workplace digitization to the creation of new economic opportunities for Quebec SMEs. Source: Authors' own elaboration (from the research data)

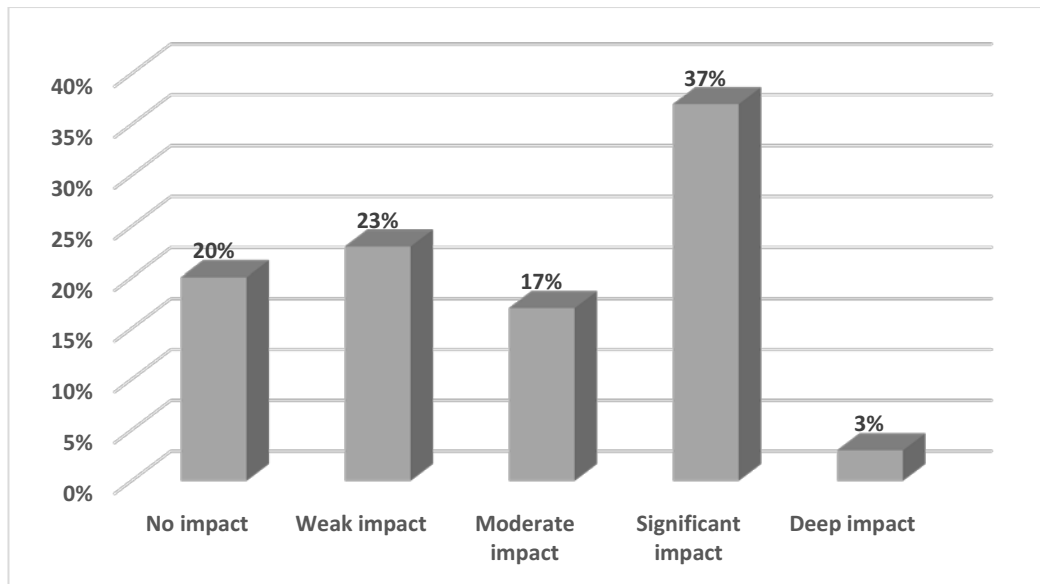


Fig. 18 Expected increase in the use of machines/robots in Quebec SMEs after digitization of the workplace. Source: Authors' own elaboration (from the research data)

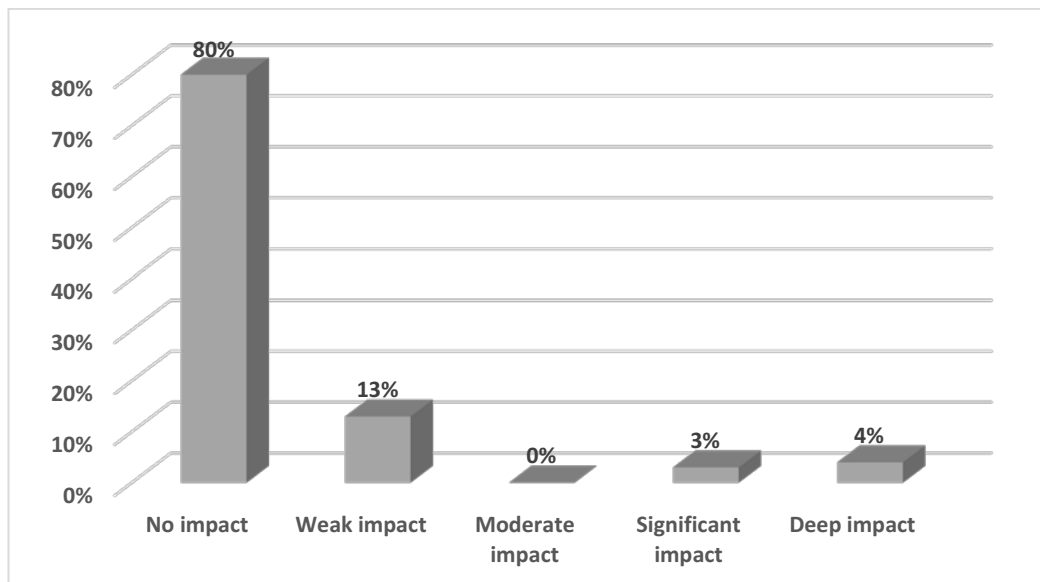


Fig. 19 Expected impact of workplace digitization on compliance with OHS legislation in Quebec SMEs. Source: Authors' own elaboration (from the research data)