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How do the technological capability and strategic flexibility of an organization impact its successful implementation of Industry 4.0? A qualitative viewpoint

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Abstract

Purpose – Industry 4.0 (I 4.0) consists of numerous digital technologies applied in organizations strategically to add value to the customer. Different organizations have varying degrees of technological capability and strategic flexibility. This paper aims to explore the relationship between technological capability and strategic flexibility on successful implementation of I 4.0.

Design/methodology/approach – A qualitative study using a grounded theory approach is conducted on 34 senior managers from Europe and North America who have implemented I 4.0 participated in this study through a theoretical sampling frame.

Findings – This study finds that technological capability and strategic flexibility have an impact on the successful implementation of I 4.0. The study also finds that different dimensions of technological capability also impact I 4.0. The interactive effect of strategic flexibility and technological capability is also noted. The study also develops a framework for successful implementation of I 4.0.

Practical implications – This study can be used by managers while implementing I 4.0 to devise a strategic roadmap for acquiring technological capability with I 4.0 technologies. Besides, it will help the managers to consider the bidirectional relationship between technological capability and strategic flexibility while formulating I 4.0 strategy for successful implementation of I 4.0 in their organizations.

Originality/value – Previous studies have examined the importance of I 4.0 technologies. However, this study extends the previous works by suggesting how technological capability and strategic flexibility can help in the successful implementation of I 4.0.

Keywords I 4.0, Strategic flexibility, Technological capability, Implementation

Paper type Research paper

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1. Introduction

Industry 4.0 (I 4.0) is the digital transformation of the business and is popularly known as the Fourth Industrial Revolution (Halpern *et al.*, 2021; Piccarozzi *et al.*, 2018). I 4.0 encompasses a plethora of digital technologies, which is transforming manufacturing and service enterprises (Nimawat and Gidwani, 2021; Spasojevic Brkic *et al.*, 2020). These technologies are classified as (1) front-end and (2) base technologies. The front-end technologies are "*Smart Manufacturing, Smart Products, Smart Supply Chain and Smart Working,*" while base technologies consist of four elements: "*the Internet of things, cloud services, big data, and analytics.*" Thus, I 4.0 implementation is the strategic application of these technologies in organizations, to create value for the stakeholders, especially customers (Frank *et al.*, 2019). To gain a competitive advantage for the organization, the application of technology in value chains should result in lowering cost or enhancing differentiation or both against competitors (Frank *et al.*, 2019; Kamble *et al.*, 2018; Porter, 1985; Tripathi and Gupta, 2021). I 4.0 is, thus, the application of technology in a strategic manner to gain a competitive advantage (Agrawal *et al.*, 2018; Lim *et al.*, 2020). Strategic application of technology may result in a technological capability that will be difficult to imitate for the organizations, and there is a need for empirical studies on technological capability and I 4.0 implementation (Azman and Ahmad, 2020; Kumar *et al.*, 2021; Sony and Aithal, 2020a, b). Therefore, the first research question in this study is:

RQ1. How does technological capability impact the successful implementation of I 4.0?

Around 70% of the digital transformation efforts fail in an organization (Li, 2020). The global lighthouse network, which is a collaboration of McKinsey and the World Economic Forum for testing digital technologies, has come to a finding that more than 70% of organizations while implementing I 4.0 only end up in the "Pilot Purgatory" phase. It is a term used wherein organizations use just a few technologies on a pilot basis without having the courage to use them on a large scale (Marco, 2021). To cite an instance, around 74% of industries have failed to capture the value of technologies such as cloud adoption (Matthias *et al.*, 2021). One of the reasons behind the failure is a lack of a cogent digital strategy to implement digital transformation or the existing strategies does not take into account the dynamics of the modern business environment (Bughin *et al.*, 2018). The modern-day business environment is turbulent, volatile, ambiguous and uncertain (Rimita *et al.*, 2020). The COVID-19 pandemic has changed the demand patterns for various products and services across sectors. It has also depicted the vulnerabilities of global supply chains and service networks (Sneader and Sternfels, 2020), and hence, organization strategy should be flexible to deal with these complexities, uncertainties, ambiguity and volatility. Organizations that have strategic flexibility can recognize problems and swiftly change resource commitments, and depending upon the external business environment will thrive in the marketplace (Benitez *et al.*, 2020; Fachrunnisa *et al.*, 2020; Yawson, 2020). In the I 4.0 era, strategic flexibility will be a critical resource that modern-day organizations use as a weapon to create competitive advantage (Haseeb *et al.*, 2019; Szalavetz, 2019). Hence, there is a need to study the impact of strategic flexibility on the successful implementation of I 4.0 (Margherita and Braccini, 2020; Sony and Naik, 2019a; Wagire *et al.*, 2021). Thus, the second research question underpinning this study is.

RQ2. How does strategic flexibility impact the successful implementation of I 4.0?

Previous studies on I 4.0 have delineated the prominence of various technologies for the success of I 4.0 (Büchi *et al.*, 2020; Cimini *et al.*, 2018; Flatt *et al.*, 2016; Frank *et al.*, 2019; de Sousa Jabbour *et al.*, 2018), but none of these studies has analyzed how the various dimensions of technology capability will impact the successful implementation of I 4.0. Likewise, the importance of strategy in the successful implementation of I 4.0 is explored in

previous studies (Erdogan *et al.*, 2018; Gupta *et al.*, 2020; Sony and Naik, 2019b; Umam and Sommanawat, 2019); however, none of the studies has examined the impact of strategic flexibility on the successful implementation of I 4.0. The uniqueness of this study is that it will help as a practical tool for organizations to build technological capability (specifically technology-acquiring capability, technology operating capability, technology shifting capability and technology upgrading capability) for successful I 4.0 implementation. Also, this study will provide organizations with a roadmap to examine their existing I 4.0 strategy for strategic flexibility. In terms of theory insights, the study extends the dynamic capability theory by identifying how technology-acquiring capability, technology operating capability, technology shifting capability and technology upgrading capability of I 4.0 impact the successful implementation of I 4.0 leading to competitive advantage. Second, it provides a starting point as regards the importance of strategic flexibility for the successful implementation of I 4.0. Third, it extends the resource-based theory to I 4.0 by suggesting the importance of tangible resources (technology) and intangible resources (strategic flexibility) for the successful implementation of I 4.0. The remainder of the paper is organized as follows. The literature review is discussed in Section 2; it is followed by methodology in Section 3. The results and discussion are implicated in Section 4, followed by Section 5 wherein conclusion, Section 6 limitation and scope for future research and in Section 7, practical implication is examined.

2. Literature review

This section reviews the literature on technology capability and strategy flexibility and its impact on I 4.0.

2.1 Technological capability and I 4.0

Technological capability rests on the foundation of a knowledge-based view of strategy. During the transformation of inputs to outputs, technology is the central element in the transformation process (Talapatra and Uddin, 2019). The two dimensions of technology are (1) hardware, which consists of an organization's machine, equipment etc., and (2) software, which consists of processes and routines for carrying out work and so on. It also consists of the knowledge of an organization's workers (Samaranayake *et al.*, 2017; Scott and Davis, 2015). Technological capability, therefore, refers to the organization's ability to be effective in using technology during the transformation process as compared to its competitors (Coombs and Bierly, 2006). The knowledge-based view of the organization argues that the knowledge component of organizational software is harder to imitate compared to the hardware component (Talapatra and Uddin, 2018). This is because of the predominance of the tacit components and will lead to long-term competitive advantage (Coombs and Bierly, 2006). Technological capability is a phenomenon that is developing over some time. It is concerned with developing or adopting modern technology. In addition to it, it also calls for developing local skills and knowledge to effectively absorb technology, improve, adapt and ultimately create new technology (Al-Mamary *et al.*, 2020). It is defined as "*combination of skills; knowledge, experiences, machines; equipment, systems and procedures that generate special advantage for an organization to perform technical functions, develop new products and processes and effectively operate company facilities*" (Al-Mamary *et al.*, 2020). The four dimensions of technology capability include technology-acquiring capability, technology operating capability, technology shifting capability and technology upgrading capability (Al-Mamary *et al.*, 2020). Technology-acquiring capability is the firm's ability to acquire new technology through formal or informal channels. The technological operating capability refers to the ability of the firm to operate the technology for use and sustain production

equipment and facilities. Technological shifting capability refers to "*capabilities to improve greatly on products and processes depending on an organizations own strength and adjust the current product and process parameters according to changing market demands*" (Guifu and Hongjia, 2009). Technology upgrading capability is the ability of the organization to upgrade their technology to meet changing market demands (Ahmad *et al.*, 2019). I 4.0 is defined as "*I 4.0 facilitates interconnection and computerisation into the traditional industry. The goals of I 4.0 are to provide IT-enabled mass customization of manufactured products; to make an automatic and flexible adaptation of the production chain; to track parts and products; to facilitate communication among parts, products, and machines; to apply human-machine interaction (HMI) paradigms; to achieve IoT-enabled production optimisation in smart factories; and to provide new types of services and business models of interaction in the value chain*". Some of the technologies that have helped in I 4.0 implementation are augmented reality, virtual reality, digital twins, COBOTS, advanced simulations, big data analytics, additive manufacturing, cloud-based systems, etc. (Kumar *et al.*, 2021; Masood and Sonntag, 2020; Neumann *et al.*, 2021). I 4.0, thus, creates a smart factory in which humans, machines and smart products communicate both physically and virtually (Neumann *et al.*, 2021). These technologies in a broad manner can be classified as front-end technologies and base technologies (Frank *et al.*, 2019; Talapatra and Uddin, 2017). Front-end technologies consider four dimensions: (1) smart manufacturing, (2) smart products, (3) smart supply chain and (4) smart working, while base technologies consider four elements: (1) internet of things (IoT), (2) cloud services, (3) big data and (4) analytics. Most organizations systemically implement front-end technologies, and it forms the central role of implementation (Frank *et al.*, 2019). The implementation of front-end and base technologies is a challenge for organizations (Bag *et al.*, 2021; Frank *et al.*, 2019), and hence, organizations will have varying degrees of technological capabilities in these technologies. Thus, there is a need for a study to analyze the technology capability of an organization and its impact on the successful implementation of I 4.0. Specifically, this study focuses on technology-acquiring capability, technology operating capability, technology shifting capability and technology upgrading capability for both the front- and back-end technologies of I 4.0.

2.2 Strategic flexibility and I 4.0

Strategic flexibility refers to the ability of the organization to sense changes in the business environment and make use of organization resources to respond to them strategically. Strategic flexibility is defined as "*as an organization's capability to identify major changes in the external environment, to quickly commit resources to new courses of action in response to change, and to recognize and act promptly when it is time to halt or reverse such resource commitments*" (Shimizu and Hitt, 2004). It is also defined as "*the ability of an organization to respond to changes in the environment in a timely and appropriate manner with due regard to the competitive forces in the marketplace*" (Das, 1995). Organizations should recognized problems and change resource commitments swiftly when organizations learn that previous strategies are not successful. Strategic mistakes can occur due to inaccurate evaluations of the business environment or due to persisting with the same strategy despite sensing environmental uncertainty (Talapatra *et al.*, 2018). It is a type of dynamic capability that makes organizations compete in dynamic markets (Eisenhardt and Martin, 2000). Strategic flexibility is the key component to break organizational inertia (Talapatra *et al.*, 2019a, b; Talapatra and Uddin, 2019). It creates flexibility in organizational forms, resource management and processes (Contador *et al.*, 2020; Matthyssens *et al.*, 2005). Strategic flexibility helps to reorganize business structures, organizing systems and other functional units (Zander and Kogut, 1995). The strategic flexibility decision-making process rests on three capabilities: (1) the organization's capability to sense negative feedback, (2) the organization's capability to objectively analyze the negative data and (3) the capability to respond to change abruptly, even during uncertain times (Shimizu and Hitt, 2004). Organizations

should correctly balance their commitment to strategy, and on the other side, timely change to the strategy so that losses can be minimized, and profits can be maximized. Therefore, maintaining strategic flexibility is one of the most important challenges organizations face in a dynamic environment. The long-term relationships that change with the implementation of I 4.0 are the interrelationships of organizational and nature, organizational and local communities, organizational and value chains, and lastly, organizational and humans (Sony and Naik, 2019b). The relationship of the organization and nature gets changed due to resource efficiency sustainability of the manufacturing system and implementation of 10R (refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle and recover) in manufacturing (Bag *et al.*, 2021; Ghobakhloo, 2020). The relationship between the organization and local communities can get changed due to the increased geographical reach of organizations due to advances in supply chains and logistics, improved customer participation as a part of the design process, cost-effective and personalized products for customers, etc. (Müller *et al.*, 2018; Rajput and Singh, 2019; Sony, 2020). Besides, I 4.0 also offers an opportunity for the depolarization of opportunities and wealth for reducing social inequalities (Sung, 2018). Even low-paying customers will also have an opportunity to customize their products (Talapatra *et al.*, 2019a, b; Talapatra and Uddin, 2019), as such society will have personalized products even for the bottom-of-pyramid markets. This could be because I 4.0 implementation will reduce the cost of products and services, due to advances in marketing and distribution models, materials, resources and production efficiencies; therefore, these products will be affordable even to bottom of pyramid customers (Strange and Zucchella, 2017). The relationship between an organization and value chains gets changed due to distributed and responsive manufacturing. This helps to design collaborative processes that enable mass customization of products and services. There is an increased demand for mass personalization of products. I 4.0 will provide the modern manufacturing enterprise with the advantages of flexibility, cost, quality, time and variety (Erro-Garcés, 2019; Rejikumar *et al.*, 2019; Wang *et al.*, 2017). The organizational and human relationship gets changed due to increased human–machine interfaces (Romero *et al.*, 2019). Within the organization, I 4.0 may eliminate low to medium-skilled jobs due to automation; however, these job losses will be offset by the creation of new jobs in areas such as informatics, mechatronics, system safety and process engineering, etc. (Bonekamp and Sure, 2015; Ghobakhloo and Fathi, 2019). The routine, monotonous and hazardous work will be done by COBOTS (Kim *et al.*, 2020), and hence, the quality of work–life will be better for employees. The smarter COBOTS now have the ability for better hazard identification and risk assessment capability; therefore, factories will be safer for humans, factories and machinery will be safer, and there will be a drastic reduction in accidents (Cherubini *et al.*, 2016). Thus, there is a need for a study to understand the impact of strategic flexibility on the successful implementation of I 4.0.

3. Methodology

The grounded theory approach was used to understand the relationship between technological, capability, strategic flexibility and the successful implementation of I 4.0. The themes that have emerged from the data by utilizing the grounded theory approach (Glaser *et al.*, 1968), therefore, help to investigate unexplored relationships. The grounded theory approach was developed by Glaser *et al.* (1968) to systematically develop theory from data using a deductive approach. The fundamental underpinning in this stance was a positivist approach. Another departure of this approach was suggested by Corbin and Strauss (2008), wherein they suggest that the grounded theory should be viewed from a subjectivist and interpretive stance. They were more critical of the fact that researcher's work and interpretation are a fundamental aspect of theory building (Corbin and Strauss, 2008). This study uses the approach suggested by Corbin and Strauss, using theoretical sampling and codification procedure. The procedure adopted is given in Figure 1. Interviews were

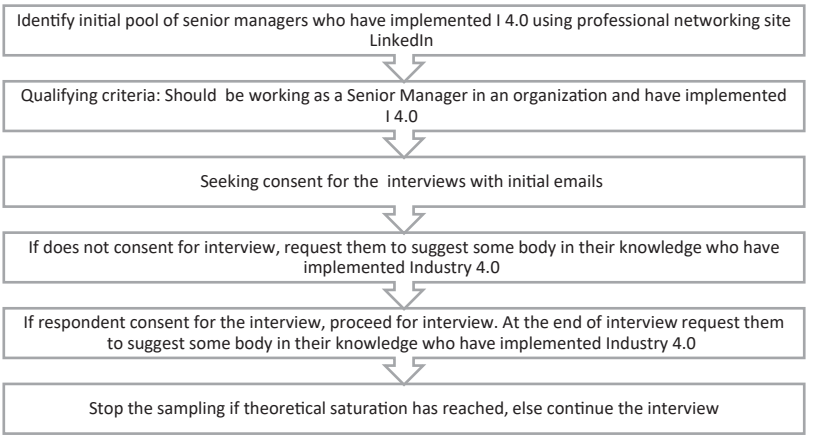


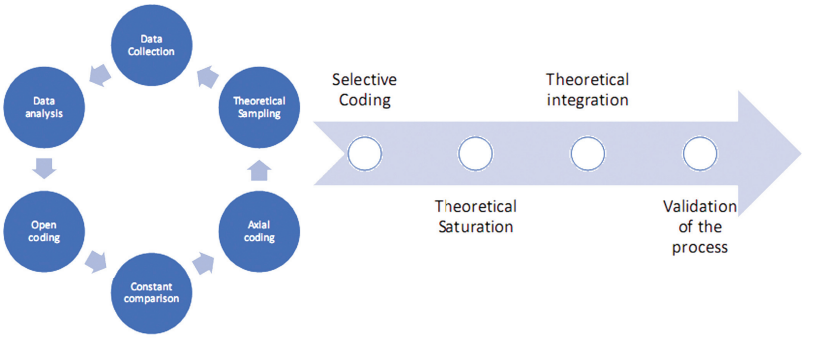
Figure 1.
Snowball sampling approach used in this study

conducted with senior managers from organizations that have implemented I 4.0 to understand the relationship between these constructs, as they have experience of implementation of I 4.0. The senior managers were selected because they are usually related to top management and plays a role in organization strategy-making (Hornsby *et al.*, 2009). The researchers used a popular professional networking site LinkedIn (Power, 2015) to identify the details of senior managers who have implemented I 4.0 in their respective organizations. Subsequently, they were contacted and given the details of the study, and they confirmed whether they have implemented I 4.0. As the study purported to examine the relationship between technological capability, strategy and success of I 4.0, it was decided to examine one senior manager from each organization. This was done to bring in diversity as regards the technological and strategic flexibility variations in the sample.

The participants who agreed formed the initial pool for the study. Subsequently, in the next phase, the principles of theoretical sampling were used through the snowball approach for finding senior managers who have implemented I 4.0 in their organizations (McCrae and Purssell, 2016). We used snowball sampling because the population size was unknown as regards the number of senior managers who have implemented I 4.0 (Yurike *et al.*, 2021). Another reason is I 4.0 is an emerging phenomenon (Agrawal *et al.*, 2021), and hence, finding senior managers who have implemented I 4.0 is difficult, and hence, snowball sampling will help to reach hard to reach communities (Biernacki and Waldorf, 1981; Handcock and Gile, 2011). They were contacted, and if they consented, the interviews continued. This study used a concept of theoretical saturation to determine the sample size. Figure 1 depicts the snowball sampling used in this study.

The grounded theory approach is an interlayered method of data collection and data analysis. The steps of the grounded theory are depicted as shown in Figure 2.

The data, which are the interview data collected, are transcribed and analyzed in the data analysis phase. The open codes are created in the open coding phase. Similar codes are grouped in the axial coding phase to create first-order categories. The theoretical sampling is further carried, out and the data collection and analyses proceed in a cyclical process. Selective coding is the last step in the grounded theory, where all categories are connected to a meta category or second-order category. Theoretical saturation occurs when no new themes emerge from the interview. In simple words, data are simultaneously gathered and analyzed (Hussein *et al.*, 2020). After 34 interviews were conducted from 34 organizations, and when no new category was emerging, it was felt that theoretical saturation (Guest *et al.*, 2006) has



Source(s): Roman *et al.* (2017)

Figure 2.
Grounded theory approach adopted for this study

occurred, and the sample characteristics are given in Table 1. A senior manager from each organization was chosen to capture the viewpoint of each organization.

In qualitative studies, low sample sizes are used unlike quantitative studies, and a sample size above ten is considered satisfactory (Dworkin, 2012; Malterud *et al.*, 2016; Marshall *et al.*, 2013). The interviews were conducted using popular video conferencing software. The average length of the interviews was between 30 and 40 min. The interview initially started with basic demographic questions, followed by open-ended questions related to I 4.0 implementation, to capture the respondents' viewpoints. Subsequently, questions such as technological capability and its impact on successful implementation were discussed. The questionnaire is given in Appendix. Strategic flexibility and its impact on the successful implementation of I 4.0 was discussed. The interviews were transcribed, and field notes were also noted. The data were analyzed using MS Excel, because it is widely available, and it has the feature of sorting, cutting, categorizing and other text-processing functions. Besides, previous studies have also used MS Excel as a qualitative data processing tool in many studies (Bree and Gallagher, 2016; Meyer and Avery, 2009). The methods of open coding, axial coding and selective coding methods were applied. The raw data are used to illustrate the findings. However, pseudo names are used to protect their identities. A systematic analytic process, including constant comparison and member-checking, was adopted to enhance credibility. Further findings were analyzed with an in-depth literature review defining concepts and the process of peer debriefing (Welch and Carter, 2020), thus adding to the further validity of the study.

4. Results and discussion

The themes that emerged in this study were (1) technological capability and successful implementation of I 4.0, (2) strategic flexibility and successful implementation of I 4.0 and,

Row labels	Female	Male	Grand total
Manufacturing	6	18	24
Service	4	6	10
Grand total	10	24	34
Age (average)	37	46	
Experience (average)	11	21	
Large enterprises	8	19	27
Small and medium enterprises	2	5	7

Table 1.
Sample characteristics

finally, (3) the interaction of technological capability, strategic flexibility and successful implementation of I 4.0.

The themes were grouped to depict the relationship between technological capability, strategic flexibility and successful implementation of I 4.0. The detailed description of the themes and the relationships are diagrammatically depicted in Figure 3.

4.1 Technological capability and successful I 4.0 implementation

Technological capability is the main resource, and therefore, it is a distinctive competence that enables organizations to create value. There are two types of technologies for I 4.0 implementation. The first one is called "Front-end Technologies," and the second "Base Technologies." The front-end technologies consider the transformation of manufacturing activities using emerging technologies such as smart manufacturing and the way products are offered smart products (Dalenogare *et al.*, 2018). Smart manufacturing uses technologies that are directed toward product processing, whereas smart products are devoted to technologies related to product offerings (Frank *et al.*, 2019). Therefore, smart manufacturing is the start of I 4.0, and the smart product is the expansion. In addition, the way raw materials and products are delivered involves a smart supply chain (Nasiri *et al.*, 2020; Zekhnini *et al.*, 2020). Additionally, the new way a worker perform various tasks and activities through the support of emerging technologies is Smart Working (Longo *et al.*, 2017; Stock *et al.*, 2018). These are called front-end technologies because these four dimensions help the organization to meet the operational and market needs. These technologies help in meeting customer needs. The main dimension is smart manufacturing, with all other dimensions interconnected to it. These front-end technologies use base technologies that are used to provide connectivity and intelligence to carry out front-end tasks. It is through the base technology that the front-end manufacturing systems are integrated. The base technologies that are present in all dimensions are the IoT, big data, cloud services and analytics (Frank *et al.*, 2019). Organizations thus will have varying degrees of technology capability.

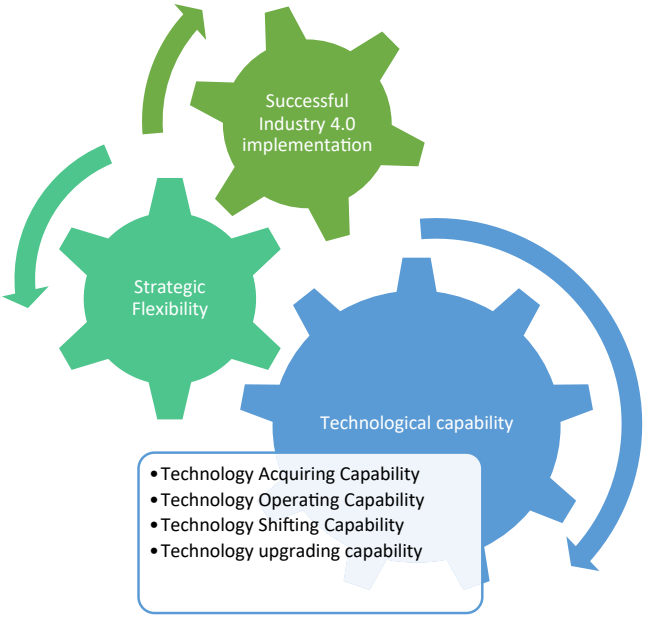


Figure 3.
Conceptual model

4.1.1 Technology-acquiring capability. The technology-acquiring capability of organizations will help to acquire both front-end and base technologies through formal or informal means. Technology acquisition will involve acquiring both hardware aspects of technology such as sensors, actuators and programmable logic controllers (PLCs), ROBOTS, COBOTS, SCADA, etc. (Frank *et al.*, 2019). In addition, I 4.0 technology acquisition would involve acquiring hardware and software for organizations such as machines, equipment, tools, technology and software (Sony and Naik, 2019b), which also consists of processes and routines for carrying out work and so on.

Participant 8: "*Organizations should have the ability to acquire these technologies for use in their organization. Acquiring technology is more than a buying process, it is a judicious technology management process wherein one assesses the match between the technological capabilities and what the market wants. Also, an organization after buying the technology should be able to absorb and make use of the technology from day one to make good quality products and services.*" The technological acquisition should be a mix of internal and external technology opportunities (Nasiri *et al.*, 2020), to establish the most appropriate source of technology acquisition in terms of capabilities, investment and scheduling requirements.

Participant 12 "*Firms should judiciously acquire I 4.0 technologies, it should first evaluate its core competence and subsequently, chalk out a technology acquisition plan which extends the core competence of organizations."* The technology acquisition team should have a multi-dimensional perspective, as the impact of technology such as IoT or cloud services or big data analytics can impact other functional departments (Papadopoulos *et al.*, 2022; Sony and Naik, 2020a); hence, technology acquisition decisions should be based on consensus. Furthermore, the team should also chalk out a plan developing competence in the acquired technology to meet the objectives of the organization.

Participant 34 "*The decision for acquiring new technology should not be based on an individual or few individuals. Rather it should be a decision that should be decided upon by taking inputs from all departments of the organization. Such a perspective to technology acquisition will bring in all departments and it will also help in developing competence within the organization.*"

The steps for technology acquisition that enable the firm to establish competitive advantage would be (1) to understand the customer needs, (2) analysis of the business model of the organization to understand the role of I 4.0 front-end and base technologies to meet the value proposition, (3) identify the technologies present in the organization and how it can complement new technology to create a competitive advantage, (4) assess the sources of technology acquisition and make technology acquisition decisions. Thus, the technology-acquiring capability of both front-end and base technologies will determine the success of I 4.0.

4.1.2 Technology operating capability. The technological operating capability refers to the ability of an organization to operate I 4.0 technology for the use, and sustenance of various activities of the organization. I 4.0 is a socio-technical system (Sony and Naik, 2020a), and hence, the role of humans is as important as technology. The employees, therefore, should be sufficiently trained to operate front-end technologies for smart supply chains, smart working, smart products and smart manufacturing.

Participant 22 "*Organizations should start using I 4.0 technology from day one. Relevant employees should be identified during the technology acquisition process and trained over time. As well, there should be the plan to use these technologies to create a competitive advantage.*"

Technologies' operating role in modern organizations is changing from mere automation to touching all facets of the business for value creation and competitive advantage.

Participant 34 *"Organizations should have a technology operating plan so that the technology is used to deliver value. I 4.0 implementation will be successful if smart manufacturing and other technologies are implemented, so organizations should think about*

immediately using the acquired technologies for manufacturing. Besides, smart products give you an immense opportunity to extend the product functions, so technology should be applied to create a unique business value."

The front-end technologies such as smart supply chains, smart manufacturing, smart working and smart products require the application of technology (Frank *et al.*, 2019). Organizations should have technology operating capability in smart supply chains in terms of technologies that are used for digital platforms with suppliers, customers and with other company units (Pfohl *et al.*, 2017). In terms of smart working, it requires technical expertise in remote monitoring of production, augmented reality for maintenance, remote operation of production, virtual reality of workers training, augmented and virtual reality for product development and collaborative robots (Elia *et al.*, 2016; El Kadiri *et al.*, 2016; Wang *et al.*, 2016a, b). In smart products, the technology operating capability is in terms of products monitoring, connectivity, optimization control and autonomy (Porter and Heppelmann, 2014). In smart manufacturing, the technology operating capability is in terms of the multitude of technologies that are used for (1) virtualization, (2) vertical integration, (3) traceability, (4) automation, (5) flexibility and (6) energy management, such as PLCs, SCADA, manufacturing execution systems, enterprise resource planning, simulation of processes and so on (Frank *et al.*, 2019).

Participant 29 "*There are different technologies of I 4.0 which will help to implement a different aspect of I 4.0. To cite an instance IIoT will help in horizontal integration of I 4.0. Hence organizations need to develop the capability to operate technology in each area of I 4.0 which will help the organization to develop the ability to operate the modern technologies of I 4.0.*"

The technology operating capability of both front-end and base technologies will thus determine the success of I 4.0.

4.1.3 Technology shifting capability. The technological shifting capability of I 4.0 technologies helps to improve smart products and processes depending on the organization's strength or unique capabilities. Besides, it will also help to adjust the product and process parameters according to the changing needs of the customers. Smart manufacturing is the main element of internal operational activities (Ahuett-Garza and Kurfess, 2018). However, smart products add to the external value addition of products. This happens when customer information and data are integrated into the production system (Dalenogare *et al.*, 2018). Both smart manufacturing and smart products can be improved by organizations to create unique products, which can be tailor-made as per the organization's strengths through the application of technology. **Participant 22** "*The organizations usually should look for ways to improve their products and process to meet market needs using modern technology. Besides, one also needs to keep in mind the strengths of the organization. For example, if an organization has a good service network, it should venture out to design new services and products based on smart product usage data, so that the existing service networks can be converted to smart products.*" **Participant 18** "*The process should be redesigned considering one core competency. If a firm has organizational learning in terms of delivering low-cost products, this should be carried forward and the I 4.0 technology should be used to further reduce the per-unit cost of the product in the long run.*" **Participant 11** "*The customer needs are changing in the era of the fourth industrial revolution. It is very dynamic, and firms should find ways of using technology to meet their needs through unique technology applications. Personalised solutions through technology will help organizations, to carve a competitive position which will benefit the organization.*" Thus, the technology shifting capabilities in terms of using both the front-end and base technologies for improved design of products and processes will determine the long-term success of I 4.0.

4.1.4 Technology upgrading capability. The technology upgrading capability is the ability of an organization to upgrade I 4.0 technology to meet changing market demands. I 4.0

technologies such as IIoT, cloud service, big data and data analytics are undergoing constant technological upgrading (Yen *et al.*, 2014). The implementation cost for many new technologies for I 4.0 will be lower once the technology matures. This could be because there would be many consultants or many case studies and literature available to aid the design of an effective implementation process once the technology matures (Ritchie and Melnyk, 2012). In addition, the probability of successful implementation of the technology would also increase, as consulting firms transfer management practices across organizations (Bloom and Van Reenen, 2010). Likewise, most organizations not only learn from direct experience but also from the experiences of others (Huber, 1991), and hence, organizations can use various strategies for the upgrading of technology.

The participants in this study echoed similar sentiments on technology upgrading.

Participant 8 "*The firms should have the ability to constantly upgrade the I 4.0 technology. Today's new technology would be tomorrow's absolute one, hence organizations should be able to upgrade technology to meet the needs of customers in a better manner.*" **Participant 10** "*The customer needs for personalised products are continuously increasing in the I 4.0 era. Organizations should constantly upgrade the existing technology, so that customer needs are met dynamically. It is not like once you switch over to new technology and you forget it, it is a continuous process of technology upgrading to meet customer needs which will help the organization.*" **Participant 32** "*I 4.0 is a paradigmatic shift wherein organizations would be using technology to gain a competitive advantage. The dynamic nature of market competition during the fourth industrial revolution will warrant constant upgrading of new technology to create a unique selling point for the organization in the customer's eyes.*" The technology upgrading capability of the organization will, thus, be a major factor that will determine the successful implementation of I 4.0 in the long run.

4.2 Strategic flexibility and successful I 4.0 implementation

Strategic flexibility has not been unanimously defined in the field of strategic management (Brozovic, 2018; Ferreira *et al.*, 2013). One of the prominent definitions of strategic flexibility by Das (1995) suggests that organizations respond in a timely and appropriate manner to the changes in the environment and the competitive forces in the marketplace. Strategic flexibility could be reactive or proactive. Reactive strategic flexibility of organizations would include the responsiveness of organizations to the changes in the business environment (Brozovic, 2018; Fernández-Pérez *et al.*, 2014) and would also transform its internal environment. Front-end technologies such as smart manufacturing, smart supply chain, smart working and smart products can be used as a lever of strategic flexibility while responding to changes in business environments. The base technologies will help in response by acting as enablers. The base and front-end technologies will help the organizations to reconfigure or reorganize the resources of organizations in a very fast manner while responding to environmental changes. **Participant 22** "*The market is extremely competitive and volatile, and hence, we need to be on guard. The strategies must be revised based on the nature of the market or of the competitive environment. A flexible strategy will be activated in an organization through the implementation of I 4.0 technologies. Therefore, flexibility in strategy will lead to the successful implementation of I 4.0.*" **Participant 31** "*Organizations need to take an active role in strategy. Big data and business analytics if used properly in an organization, will help the organization to understand the business environment in a data-oriented manner. Thus, I 4.0 implementation will help organizations to understand if existing strategies are doing well, or whether it needs to revise its strategies, on whether the organization should enter new markets or launch new products.*" **Participant 14** "*I 4.0 implementation will help organizations to implement its strategy and measure its performance within the organization in a dynamic manner. Resource mobilisation will be faster if the assets are integrated by technology to function strategically.*"

Another aspect of strategic flexibility is intention. The intention of the organization is in terms of whether the organization uses an offensive strategy or defensive strategy and measures it takes to remain flexible while implementing strategy (Evans, 1991; Ling-Yee and Ogunmokun, 2013). I 4.0 technologies such as smart manufacturing will help to implement offensive strategies for capturing market share by implementing smart and personalized products (Nunes *et al.*, 2017). Technologies such as big data can help in defensive strategies to retain customers, by analyzing the product usage data and giving them specialized services (Vendrell-Herrero *et al.*, 2017), which will help retain customers. **Participant 6** "*If an organization wants to capture larger markets, I 4.0 technologies can help in both volume and variety due to the advances in manufacturing technologies. Thus, depending upon an organization's strategy, the I 4.0 technologies will be a great help to implement it.*"

Organizations should act swiftly to the changes in the external business environment and should also constantly develop, change and reframe their strategies over long periods to be strategically flexible. I 4.0 technologies due to information and communications technology (ICT) integration will help in the swift implementation of strategies due to technologies such as smart supply chain, smart products, smart working and smart manufacturing, as these are digitally integrated as an ecosystem that can be controlled digitally (Nadkarni and Narayanan, 2007; Srivastava, 2014). Similarly, I 4.0 base technologies such as IoT, big data and data analytics will help in analyzing the impact of these strategies dynamically on various key performance indicators (KPIs) so that strategies can be devised and implemented. **Participant 18** "*Strategy can be easily implemented through I 4.0 very quickly so that organizations can immediately respond to environmental demands.*" **Participant 30** "*Modern technologies will help organizations to monitor the various parameters which will help to understand strategic implications. Suppose an organization implements supply chain excellence so that customers can track the orders and as well reduce delivery times. These parameters can be systematically monitored by intelligent algorithms which help us to understand the performance in a time-oriented manner.*"

The strategic flexibility could be time-oriented, such as short, medium and long term (Carlsson, 1989; Golden and Powell, 2000). I 4.0 technologies front-end and base technologies will help in the implementation of time-oriented strategic flexibility. Therefore, strategic flexibility will impact the successful implementation of I 4.0 in an organization.

4.3 Interaction of technological capability and strategic flexibility on the successful I 4.0 implementation

Strategic flexibility is the ability of organizations to respond to changes in the environment. Environmental changes could be competition, uncertainty, volatility, etc., and these changes could be intermittent disturbances, continuous, expected or unexpected. Different firms will respond to changes in the environment in a different manner (Brozovic, 2018) by using organizational resources as per the strategy designed. Technological capability is one of the most important resources an organization can use while implementing I 4.0 in an organization (Sony and Naik, 2020b). There are two viewpoints expressed by the respondents in this study. The first talks about strategic flexibility having an impact on technology capability. The second talks about the impact of technology capability on strategic flexibility. The first one talks about how strategic flexibility would warrant technology capability in terms of new technology-acquiring capability, technology operating capability, technology shifting capability and technology upgrading capability. Strategic flexibility would also mean phasing out some technological capability and dynamically acquiring new capabilities to meet the needs of the organization. **Participant 16** "*Organizations while responding to competitors will need to sometimes buy new I 4.0 technologies or phase out old ones. This must be done very swiftly. This is a dynamic process which happens at various life stages of the organization while implementing I 4.0.*" The second viewpoint stems from the fact that the technology capability has also an impact on strategic flexibility. The organization responds

to the external business environment by keeping in mind the resources at the organization's disposal. This is because acquiring new resources requires time and money, so most organizations respond to environmental disturbances, which are temporary, using existing technological capability. **Participant 4** "*Most organizations respond to a competition or changing markets using existing technological resources of I 4.0 that an organization possess at that time. Acquiring new resources is sometimes difficult as top management may not approve these as it requires investment and expenditure. So, usually, the responses of an organization are to utilize the existing resources or capabilities of I 4.0.*" Both viewpoints suggest that there is bidirectional interaction between technological capability and strategic flexibility for the successful implementation of I 4.0.

5. Discussion

This study depicts the importance of technology-acquiring capability and strategic flexibility for the successful implementation of I 4.0. The dynamic capability framework is one of the leading frameworks in strategy management, which explains the firm-level heterogeneity in terms of long-run growth or survival, stagnation, growth or failure (Teece, 2017). The dynamic capability stresses knowledge as a core capability that distinguishes firms and provides a competitive advantage (Leonard-Barton, 1992). The four dimensions of core capability could be (1) competence, skills and knowledge of employees; (2) technical systems; (3) managerial systems; (4) values and norms; etc. (Garbellano and Da Veiga, 2019). The technology-acquiring capability of organizations to acquire both front-end technologies and base technologies of I 4.0 will result in core capabilities in technical systems in both hardware and software aspects of technology. This will help the organization to acquire both front-end and base technologies of I 4.0 to build, integrate, reconfigure existing/new technology to create both internal and external competence to address volatility, uncertainty, complexity and ambiguity (VUCA) (Bundtzen and Hinrichs, 2021) business environment leading to competitive advantage. Therefore, we propose.

P1. The organization is more likely to be successful in implementing I 4.0 if they can acquire both front-end and base technology of I 4.0 to create a competitive advantage.

The technology operating capability of an organization in terms of both front-end and base technologies of I 4.0 will result in for use, and sustenance of various technologies for the organization, which will result in dynamic competence, skills and knowledge of employees to meet the goals and objectives, resulting in a sustainable competitive advantage. The employees by acquiring the technology operating capability will create learned and stable patterns (Zollo and Winter, 1999) of I 4.0 technology operation, which can be used systematically to generate/modify its operational routines to meet the vision, mission, goals and objectives of the organization better than its competitors. We propose.

P2. Organizations can create competitive advantage through I 4.0 front-end and base technologies operating capability by creating operational routine through its employees to meet the vision, mission, goals and objectives of the organization.

The organizations should use the I 4.0 front-end and base technologies technological shifting capability to improve the existing products and processes depending on the needs of customers. Organizations should use I 4.0 technology shifting capability in a three-pronged manner. First, they should identify, understand the needs of the customers using I 4.0 technologies such as data analytics; second, they should use resources to meet design products and services to meet the needs using technologies such as social manufacturing; and third, make efforts for continuous renewal of these efforts in a dynamic manner using feedback from customers for creating a competitive advantage. Therefore, we propose.

P3. Organizations can gain a competitive advantage if I 4.0 front-end and base technology shifting capability are dynamically used by organizations to create products and services to meet customer needs.

I 4.0 front-end and base technologies are undergoing new developments, and organizations that have the technology upgrading capability, to upgrade their existing technology will help to meet the demands of customers. I 4.0 technologies are constantly changing, and new products and services need to be introduced to meet the changing market needs (Khanzode *et al.*, 2021; Nara *et al.*, 2021). Therefore, organizations that make managerial decisions for technology upgrading capability to meet the objectives of organizations will be able to sustain their competitive advantage and we propose.

P4. Organizations to sustain the competitive advantage should have the competency in technology upgrading capability of I 4.0 front-end and base technology to meet the needs of the organization.

The pandemic has created an atmosphere of VUCA in both supply and demand scenarios for an organization (Lancet, 2020; Murugan *et al.*, 2020). Besides, the competitive forces, which are acting on an organization, are increasing due to the digital transformation of various organizations (Hanelt *et al.*, 2021) and increasing customer needs (Vidili, 2021). The ability of the organization to respond in a timely and appropriate manner to meet these changes in the business environment using strategic flexibility in terms of both front-end and base technologies will enable the successful implementation of I 4.0. Those organizations which can devise strategies, mobilize I 4.0 resources, realign assets and competence to meet the changing business environment will develop a competitive advantage and we propose.

P5. Organizations that can respond in a timely and appropriate manner using I 4.0 technologies to the VUCA environment and the competitive forces in the marketplace will have a sustainable competitive advantage.

Strategic flexibility and technological capability are interrelated to each other in the organizations. This view stems from the fact that strategic flexibility would need technology capability in terms of new technology-acquiring capability, technology operating capability, technology shifting capability and technology upgrading capability of I 4.0 front-end and base technologies. In addition, technology capability has also an impact on strategic flexibility because the organization responds to the external business environment by keeping in mind the resources at the organization's disposal of I 4.0 front-end and base technologies. Hence, we propose.

P6. Organization should consider the interaction between strategic flexibility and technological capability with I 4.0 front-end and base technologies, for the successful implementation of I 4.0.

Figure 4 depicts the framework for competitive advantage and successful implementation of I 4.0. It consists of four layers: (1) base technology layer, (2) front-end technology layer, (3) technology capability and strategic flexibility layer, and (4) competitive advantage layer. The base technology layer consists of technologies such as cloud, IoT, big data and analytics. These layers provide connectivity and intelligence to front-end technologies, and hence, it is a strategic exercise. The front-end technologies form a major part in vertical, horizontal and end-to end integration of a smart factory (Wang *et al.*, 2016a, b). Hence, base technologies should be carefully selected, implemented and operated based on their capability to achieve competitive advantage. The front-end technology layer consists of smart manufacturing, smart products, smart working and smart supply chain. These are the I 4.0 technologies that are concerned with operational and market needs. Organization should first understand the market needs,

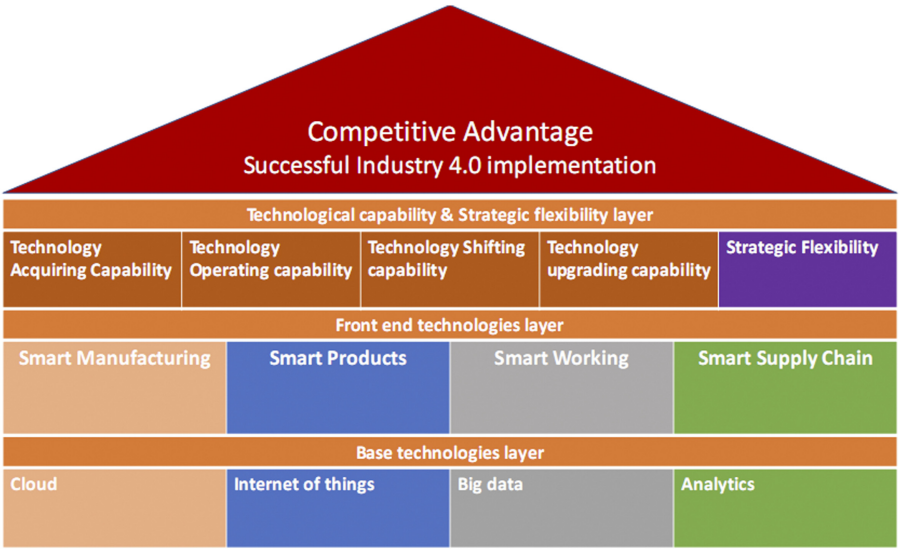


Figure 4.
Framework for competitive advantage and successful I 4.0 implementation

subsequently develop strategies for acquiring, operating, shifting and upgrading capability in each of these technologies, by keeping in mind the vision, mission and goals of the organization. The technological capability and strategy flexibility layer depict how an organization can respond in a timely and appropriate manner using both front-end and base technologies to meet the needs of market place. The modern market needs are dynamically changing due to VUCA and other the competitive forces; thus, this layer attains perennial significance. The organizations should make use of front-end, base technologies, in addition to technological capability and strategic flexibility in an optimum manner to meet the dynamic needs of the market. In addition, the organizations should also consider the interactive effect of front-end and base technologies, technological capability and strategic flexibility while implementing I 4.0 in their organizations. The fourth layer of the framework is about attaining competitive advantage. I 4.0 is not just implementation of technologies in isolation, rather organizations need to develop dynamic capability specifically in terms of acquiring, operating, shifting and upgrading capability in both front-end and base technologies in a continuous manner to attain a sustainable competitive advantage. The I 4.0 implementation will be a success in the long run if the organization can sustain the competitive advantage using each of the layers of the framework.

6. Conclusion

The study investigates the relationship between technology capability, strategic flexibility and successful implementation of I 4.0. Our study illuminates that the four dimensions of technology capability impact the successful implementation of I 4.0. Besides, organizations that excel in all four dimensions will create a sustainable competitive advantage for the organizations. The strategic flexibility of an organization in terms of timely and appropriate responses to the VUCA business environment also impacts the successful implementation of I 4.0. The technology capability and strategic flexibility interact bidirectionally and will hence be an important factor for the successful implementation of I 4.0.

7. Limitation and scope of future work

The limitation of the study is that data were only collected from two continents Europe and North America, as the I 4.0 concept is well received and established within these continents.

Besides, these are developed countries, and hence, the findings can be generalized to the socio-economic-cultural context where the organization is located. Future studies should also study the relationship in developing countries and compare the same with developed countries to understand the strength of relationships.

Future studies should quantitatively test the relationship between technological capability, strategic flexibility and successful implementation of I 4.0. The moderating factors such as type of organization, sector, organizational culture and leadership could be some of the variables whose impact should be studied to understand the nature of the relationship. In this, strategic flexibility and success of I 4.0 implementation was conceptualized as a unidimensional construct in the context of I 4.0 implementation. Future studies should re-examine these constructs for multidimensionality. Case studies will also help to understand the longitudinal relationships between technological capability, strategic flexibility and successful implementation of I 4.0.

8. Practical implications

This study offers practical implications for managers and policymakers. Managers can use this study before implementing I 4.0 to understand the importance of developing technological capability for both front-end and base technologies of I 4.0. Managers should understand that in this VUCA and technological competitive market, managers should develop a roadmap for their organizations from developing technology acquiring capability to gain competitive advantage. There is a large number of digital technologies for I 4.0 implementation, and it creates ambiguity as regards its adoption in an organization (Hanelt *et al.*, 2021). Every technology should be evaluated in terms of how it will help to improve the value chain or will this new technology help to develop a new business model to create new value for the firm, or in simple words, help to create new revenue streams. Once this decision is made regarding the technology, a strategic roadmap should be created to develop the technology-acquiring capability. This is a strategic process, and a decision should be made after studying the existing technologies and business model of the organization so that decisions can be made for technology acquiring in terms of cost, time, technical know-how, contracting, licensing, research and development (R&D), training, supplier management, etc. Some of the major options of technology acquisition of I 4.0 technology are whether to buy, lease, outsource or develop within an organization. This is a pivotal decision, and it will in the long run help to gain a competitive advantage. This study also stresses the importance of technology operating capability for the successful implementation of I 4.0 in an organization. Managers should ask themselves how they can develop expertise in technology operating capability to meet the goals and objectives of the organization. Managers should examine the existing product portfolio and use I 4.0 front-end and base technologies to develop products and services to meet the changing needs of the organization. Efforts should be made by managers to acquire the technology shifting capability with I 4.0 technologies. Technology upgradation is a key feature to sustain the competitive advantage gained by technology adoption. This study stresses that managers should evaluate the latest developments in front-end and base technologies of I 4.0 and efforts should be made to upgrade the existing technologies if it benefits the organization to better meet the goals and objectives. Another pertinent point managers should consider in decisions on technological capability building and strategic flexibility is that they are bi-directionally related to each other. In simple words, change in one leads to an impact on the other, and vice-versa. Managers should ask how we can develop the technological capability so that it can help the organization to respond in a timely and appropriate manner to changes in changing business environment and VUCA. Managers should devise strategies for technological capability and strategic flexibility considering the interaction both can have on each other and how both can help in the successful implementation of I 4.0.

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Appendix
Questionnaire

1. Name (optional)
2. Gender
3. Which country you are based at present?
4. Age in years
5. Organization & Department (Optional)
6. Designation
7. Years of experience
8. Which of the following sectors do you work?

    Manufacturing

    Service

    Public Sector

9. How many employees are there in your organization?

    0 to 50

    50 to 250

    Above 250

10. Have your organization implemented Industry 4.0?
11. If no, why? ……
12. If yes, continue further.
13. When did you organization implement Industry 4.0?

    1 to 3 years

    3 to 6 years

    6 to 10 years

    Above 10 years

14. According to you was Industry 4.0 initiative a success?
15. If yes, why?
16. If No, why?
17. What are you views on technological capability of an organization after Industry 4.0 implementation?
18. In your organization what was the impact of technological capability after implementing Industry 4.0?

19. How does technological capability impact the successful implementation of Industry 4.0?
20. According to you, in your organization how did technological capability affect the Industry 4.0 success?
21. How does organization strategy affect the implementation of Industry 4.0?
22. According to you, how does strategic flexibility impact the successful implementation of Industry 4.0?
23. According to you, does your organization has strategic flexibility?
24. If yes, why do you think so?
25. If no, why do you think so?
26. How did strategic flexibility impact the implementation of Industry 4.0, in your organization? Please elaborate with examples from your organization?
27. According to you, how does strategic flexibility and technological capability interacts to create successful implementation of Industry 4.0?

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