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SWOT analysis for smart factories

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Abstract

The third industrial revolution introduced automation technology to factories. Thanks to this technology, the process of automation of repetitive processes in factories began. This process is unidirectional and can be expressed as the implementation of human commands by the machines (robots, conveyors and other machines) in the factory without any modification. With the Fourth Industrial Revolution, machine and human collaboration has gained importance and the concept of smart factory has come to the fore. Smart factories have both advantages and weaknesses, opportunities and threats.

This study aims to examine the advantages and opportunities, weaknesses and threats that the smart factory infrastructure can provide to businesses by using the SWOT analysis method. In this context, document analysis, one of the qualitative analysis techniques, was used in the study. The study sample consists of all documents in the references section. The snowball method was used in sample selection. As a result of the study, it was seen that the smart factory infrastructure provides great advantages to businesses. However, it is concluded that cyber security threats and unqualified employees are among the issues that need to be emphasised by businesses.

Keywords: Digital Transformation, Knowledge Management, Smart Factories, Technology and Innovation Management

JEL Codes: M10, M15, M19, O39

1. Introduction

Although the smart factory concept conjures up images of technological objects such as autonomous machines, robots and digital displays, these technologies predate the smart factory concept. At the core of smart factories is the data-knowledge cycle. The data-knowledge cycle is the process of analysing the data obtained from the smart factory components and transforming it into knowledge, and sharing the transformed knowledge with the smart factory components so that the smart factory process can be maintained efficiently.

Knowledge has always had an essential place in the lives of human beings. With the development of technology, the importance of knowledge has not changed, but the methods of acquiring (Nowacki & Bachnik, 2016), sharing (Santoro et al., 2018) and producing new knowledge from knowledge have changed. Those who use these methods have the power of knowledge. To acquire knowledge in smart factory infrastructures, data, which is the building block of knowledge, is collected from elements such as machinery, equipment and people (Chen et al., 2017), through advanced sensors, internet and wireless communication infrastructure, and mobile technologies (such as 4G, 5G) (Xu et al., 2021; Shi et al., 2020). From the collected data, artificial intelligence and different software technologies are used to extract the necessary knowledge to maintain the smart factory infrastructure. This process, from data to knowledge, constitutes the data-knowledge cycle (Grabowska, 2020; Padovano et al., 2018; Resman, Turk & Herakovic, 2020; McLaughlin, 2020). Business functions such as production, marketing and logistics, which are subject to the data-knowledge cycle, have started to be called smart production, smart marketing and smart logistics.

The inclusion of automation technologies in factories has started the era of unidirectional automatisation in factories. Unidirectional automatisation can be expressed as the implementation of commands given by humans in automation systems by machines (robots, conveyors and other machines) in the factory without any modification. Thanks to the discovery of the Internet, advances in communication

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technologies and ever-evolving technology, the first signs of a new revolution in industry have emerged. The new revolution, dubbed Industry 4.0 in 2011, introduced the concept of bi-directional automatisation in factories by leveraging the data-knowledge cycle. Bi-directional automatisation is the realisation of machine-machine, machine-employee and employee-employee collaboration with the help of technological innovations within the scope of the data-knowledge cycle. In this way, the concept of the smart factory has emerged (Xiong et al., 2023; Ling et al., 2020; Soetanto et al., 2015; Liu et al., 2022).

In the literature on smart factories, there is only one study on the Sri Lanka industry within the scope of SWOT analysis. This study examined strengths, weaknesses, opportunities and threats related to the transition of small and medium-sized businesses to smart factory infrastructure within the Sri Lankan industry (Leem and Lee, 2018). However, there is no SWOT analysis in general within the scope of smart factories. Within the scope of this study, smart factories will be analysed in terms of knowledge management. In addition, a SWOT analysis will be conducted to evaluate smart factories' strengths, weaknesses, opportunities, and threats. Document analysis, one of the qualitative analysis methods, was used in the study. Document analysis was chosen as the data collection method. The study sample consists of all documents specified in the references section of the study. The sample of the study was determined by the snowball method.

2. Smart Factory Concept

The foundation of smart factories is based on the sciences of cybernetics and electronics, first introduced by Al-Jazari, a Muslim Turkish scientist from Artuqid, who lived about 900 years ago. Cybernetics is the science of communication, control, balance and adjustment. In light of this science, automation systems, artificial intelligence, electronic brains, and systems have emerged. A robot that could move and perform some movements on its own, unprecedented in the history of the world until that day, was given to the Artuqid ruler Mahmud bin Mehmed by Al-Jazari. Al-Jazari's discoveries were collected in his work Kitâb-ül-Hıyel (The Book of Devices) (Külcü, 2015; Türkiye Newspaper Encyclopedia Group, 2005).

A smart factory can be defined as a collection of interconnected machines, devices, production systems (Chen et al., 2017), employees, in-plant departments, suppliers (in short, all objects) (Schniederjans, Curado & Khalajhedayati, 2020), and their representations in cyberspace (Shi et al., 2020) that use the latest technologies to collect continuously (Nowacki & Bachnik, 2016) and share (Santoro et al., 2018) data. In this context, smart factories transform the data acquired from processes such as production, marketing, sales, finance, accounting, human resources, and supply chain into knowledge (Osterrieder, Budde & Friedli, 2020). This enables collaboration between the factory's internal environment (such as employees, machinery and equipment, and in-plant departments) and its external environment (such as suppliers, customers, and government) (Fakhar Manesh et al., 2021). The collaboration in the internal environment of the factory is called vertical integration, while the collaboration in the external environment is called horizontal integration. The resulting structure of smart factories is a factory infrastructure with complete vertical and horizontal integration (Burke et al., 2017). However, since horizontal integration is dependent on the external environment of the smart factory, horizontal integration may be the most challenging process to complete in the smart factory process. Horizontal integration helps the emergence of new value networks and, accordingly, new business models (Wang et al., 2016).

A smart factory structure within the scope of horizontal and vertical integration is depicted in Figure 1.

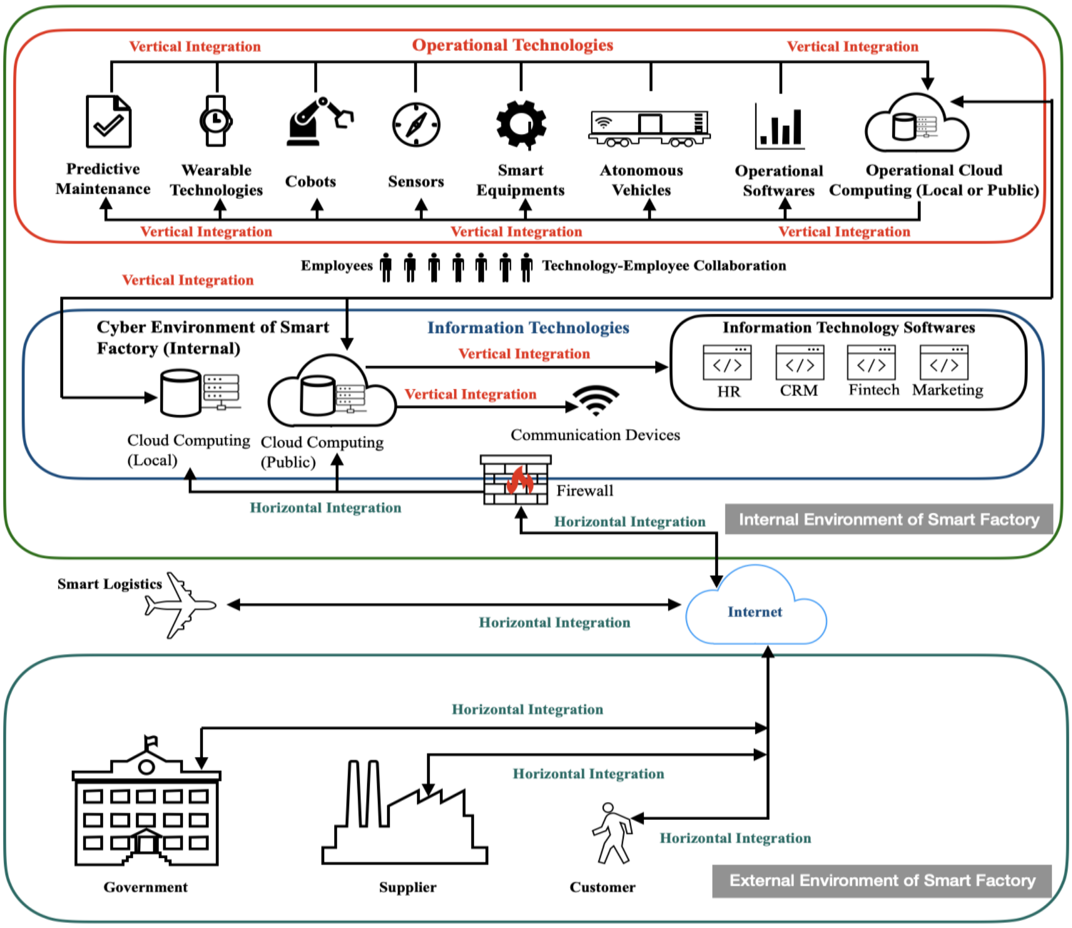

Figure 1. Smart factory infrastructure within the scope of horizontal and vertical integration (Source: Yoşumaz, 2024)

Six components are needed to achieve horizontal and vertical integration in smart factories. If the smart factory infrastructure is compared to an atom, the atom's core is the data-knowledge cycle component. The other components around the nucleus fulfil the necessary tasks for the data-knowledge cycle to work seamlessly. The atom metaphor can be expressed as in Figure 2.

Figure 2. Demonstration of Smart Factory Components with Atom metaphor (Source: Author Elaboration - Illustrated with Microsoft PowerPoint Software)

All six components in the atomic metaphor work in collaboration with each other to form the smart factory infrastructure.

a. Data-Knowledge Cycle: Data acquired from systems related to operational technologies, such as machinery and equipment used in smart factories (Soori, Arezoo & Dastres, 2023) and data acquired from systems related to information technologies, such as human resources, finance and accounting management are stored in data storage and computing systems of businesses (Napoleone, Macchi, and Pozzetti, 2020; Osterrieder, Budde and Friedli, 2020). These stored data are transformed into knowledge by loading information with various analysis methods. The transformed knowledge can be used to optimise the systems from which the data are acquired, optimise the efficient execution of business processes, and optimise the decision-making structures of businesses (Abubakar et al., 2019; Ode and Ayavoo, 2020). The knowledge used leads to data re-generation in operational technologies or information technology infrastructures. This process can be described as the data-knowledge cycle. However, the data-knowledge cycle enables the collaboration of operational and information technologies. This collaboration paves the way for the formation of a digital ecosystem. (Apilioğulları, 2021) The data-knowledge cycle can be briefly described in Figure 3.

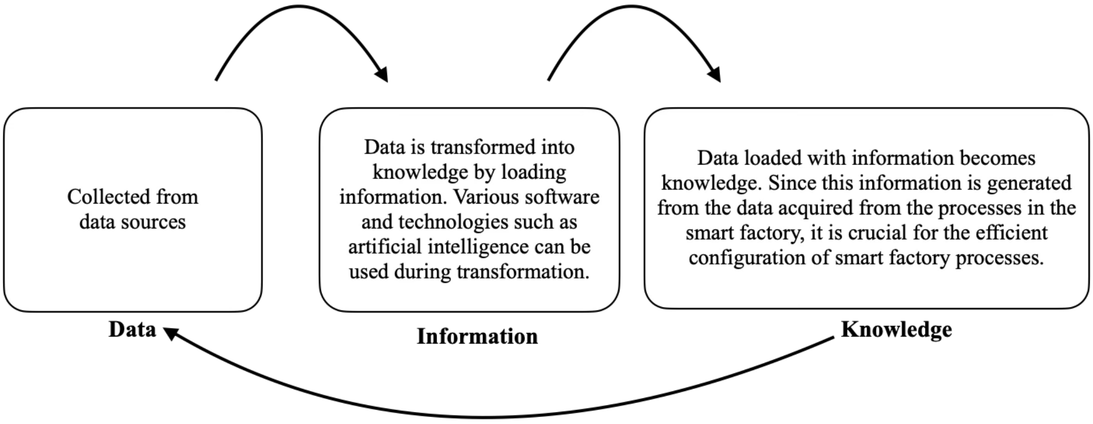

Figure 3. Data-Knowledge Cycle (Source: Author Elaboration - Illustrated with Apple Pages Software)

Every object in a smart factory should be considered within the data acquisition framework (Mabkhot et al., 2018). Because objects that can be acquired data can be transferred to cyber environments (such as data storage systems and cloud computing systems) owned by smart factories as cyber objects. Duplicates can be generated in the cyber environment of the processes to which the objects transferred to the cyber environment belong. Duplicates of objects or processes in cyberspace are called digital twins (Wan et al., 2018; Kalsoom et al., 2020; Dornhöfer et al., 2020). Thanks to the digital twin, processes in smart factories can be simulated in cyberspace. For example, before starting a production phase, inefficient conditions in production can be eliminated by simulating production in the cyber environment.

b. Technologies Used to Collect and Share Data: The technologies that collect and share data in smart factories are divided into operational and information technologies (Chang, Tu, and Huang 2021). Within operational technologies, data is collected from machinery, equipment and sensors in the factory environment with software infrastructure. However, wearable technologies used by employees can also be considered within the scope of operational technologies. The collected data is analysed and transformed into knowledge with artificial intelligence (AI) and generative artificial intelligence (Gen AI) supported software and then shared with technologies such as virtual reality, augmented reality, and autonomous vehicles. Within the scope of information technologies, data is collected through tablets, cell phones and computer software. After the collected data are analyzed with AI and Gene AI-supported software and transformed into knowledge, they are shared with departments such as human resources, marketing, and management (Grabowska, 2020; Padovano et al., 2018; Resman, Turk & Herakovic, 2020; McLaughlin, 2020).

Wireless technologies such as Wi-Fi, 4G, 5G, LoRa Networks and wired fibre infrastructure are used in the data collection infrastructure of both operational and information technologies. The systems (cloud computing systems) where the collected data will be stored, and the necessary analyses will be performed within the scope of the data-knowledge cycle can be hosted in the factories' local centres or can be obtained from service providers providing cloud computing services (Xu et al., 2021; Shi et al., 2020).

Operational technologies include predictive maintenance, wearable technologies, cobots, machine management software, autonomous goods transportation and software infrastructure (Paulsen, 2020; Lee, 2021). Operational technologies are shown in Figure 4.

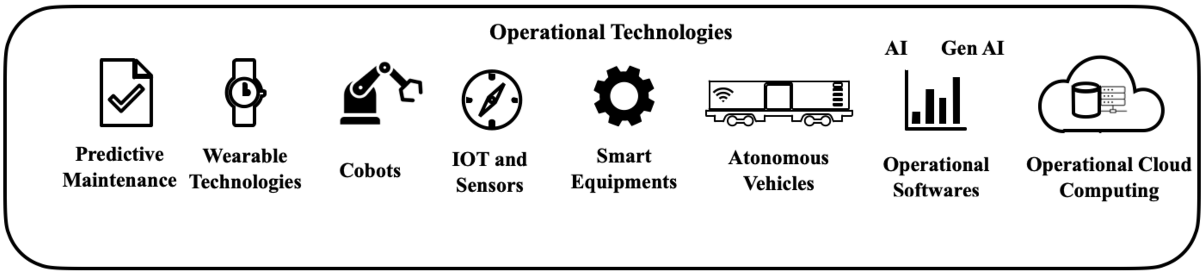

Figure 4. Operational Technologies (Source: Author Elaboration - Illustrated with Apple Pages Software)

Information technologies form the infrastructure of processes such as human resources, finance, accounting and business management with private or public cloud computing infrastructure, communication devices (such as switches and points), human resources (HR), customer relationship management (CRM), finance-technology collaboration software (fintech) and software used in marketing infrastructure (McLaughlin, 2020; Kuang,, 2021; Jiang 2023; Beulen & Bode, 2021; Zhang, Xu & Ma, 2023). Information technologies are shown in Figure 5.

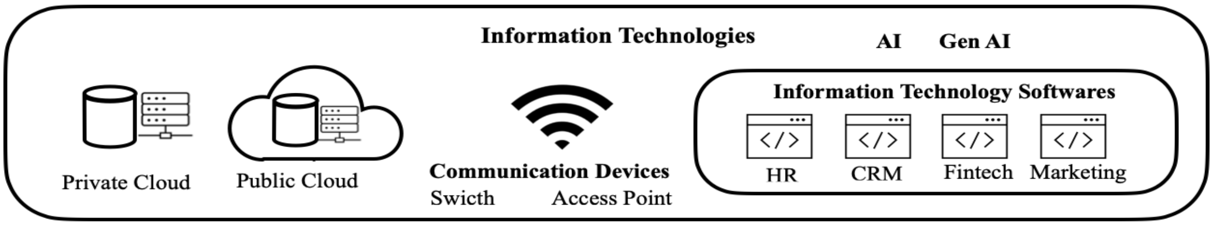

Figure 5. Information Technologies (Source: Author Elaboration - Illustrated with Apple Pages Software)

c. Software Component: All processes of smart factories are managed with software infrastructure. In general, smart factory management software should be able to work with data collection infrastructure, visualise data, manage processes in smart factories, perform data analysis, have a decision support structure, and talk to other management software with APIs (Stojanov et al., 2021; Amazon Web Services, 2023).

There is no software that can manage all the processes of smart factories within the scope of information and operational technologies. It is challenging, but not impossible, to gather all of these processes under a single software. For this reason, the software to be used in smart factories is coded to fulfil various tasks. For example, CAD / CAM (Computer-Aided Manufacturing / Copmuter-Aided Design) software has been developed for the virtual modelling of a product in production, MRP (Material Requirements Planning) software for the planning of materials in production, MES (Manufacturing Execution System) software for the execution of production processes, CMSS (Computerised Maintenance Management System) software for machine and equipment maintenance (Bremner, Eisenhardt & Hannah**,** 2017; Ortiz, Marroquin & Cifuentes, 2020; Hozdić, 2015; Chen et al., 2017). To gather all of these software under a single roof, a management software to be developed must support the API (Application Programming Interface) infrastructure and be able to work in collaboration with the relevant software via API.

d. Technological Developments: Technologies such as virtual reality (VR), augmented reality (AR) (Manufacturing 2016; Maly, Sedlacek, and Leitao 2017), digital twin (Boschert & Rosen, 2016; Tao et al., 2019), 3-D printers (Floyd, Wang & Regens, 2017), cobots (Raffik et al., 2023) are important for establishing the data-knowledge cycle in smart factories effectively and efficiently. The inclusion of automation technologies into factories has started the revolution of unidirectional automatisation in factories. Unidirectional automatisation can be expressed as the implementation of the employees' commands in automation systems by the machines (robots, conveyors and other machines) in the factory without any modification. In Unidirectional automatisation, there is no attempt to acquire data. For this reason, the data-knowledge cycle has not been fully established. With the discovery of the internet, developments in communication technologies and the Industry 4.0 process that emerged thanks to the ever-evolving technology, smart factory infrastructures started to be established, and the importance of bi-directional automatisation in factories was realised (Ferber, 2013; Heynitz et al., 2016; Lee, Bagheri & Kao, 2015; Davies, 2015). Bi-directional automatisation in smart factory infrastructures is the realisation of machine-machine, machine-employee, and employee-employee collaboration with the help of technological discoveries within the data-knowledge cycle (Xiong et al., 2023; Ling et al., 2020; Soetanto et al., 2015; Liu et al., 2022). For example, as a result of the analysis of the data acquired from a production process with IOT (Internet of Things) infrastructure, the knowledge about the production process can be instantly displayed on the tablet computers of the employees with augmented reality infrastructure. In this way, employees can instantly access detailed information about the production process. In cases where intervention in the production process is required, the intervention process is carried out in a controlled manner.

e. Organisational Structure: The organisational structure relates to the stakeholders in the factory's internal and external environment. There are components such as employees, corporate culture, business departments, and management in the factory's internal environment, and components such as suppliers, customers, and the government in the external environment. The fact that these components work in collaboration and use technological infrastructures that can communicate with each other contributes to the efficient operation of the data-knowledge cycle (Yogesh, 2000; Buntak, Kovačić & Martinčević, 2020; Leal-Rodríguez et al., 2023; Bagdasarov, Martin & Buckley, 2018; Salvadorinho & Teixeira, 2021).

f. Cyber Security: Cyber security in smart factories is an important issue that concerns all smart factory components. Cyber security measures in smart factories differ regarding operational and information technologies (Flatt et al., 2016; Li et al., 2023; Hajj et al., 2020; Botta et al., 2023). Within the scope of cyber security measures of information technologies, measures such as firewalls, antivirus applications, technologies such as IPS / IDS, and timely application of system update patches are generally taken (Safaei Pour et al., 2023; Baraković & Baraković Husić, 2022; CLIM, 2019; Hajj et al., 2020). Cyber security measures of operational technologies are a process that should be evaluated more comprehensively than information technologies. System update patches to be made within the scope of operational technologies may bring about a more complex process, unlike system update patches in information technologies. Since the systems' lifetime in operational technologies may be long, the systems in operational technologies may have old infrastructures. Updates to these infrastructures may require system downtime. In some cases, it may not even be possible to update. This situation may cause many cybersecurity vulnerabilities (Hajj et al., 2020). The spread of cyber security threats of operational technologies to the products used by customers in the external environment of the factory can bring big problems. For this reason, cyber security measures of operational technologies should be given importance.

3. Methodology

In this study, a SWOT analysis was conducted by examining the strengths, weaknesses, opportunities and threats of the smart factory infrastructure. This study employed document analysis as the method for data collection. The collected data was then analyzed using SWOT analysis, a descriptive analysis method within the qualitative analysis. Document analysis can be used as a qualitative analysis method on its own or to support other qualitative analysis processes (Sak et al., 2021). The population of the study consists of all articles written in the context of smart factories. From this population, 44 documents were obtained using the snowball sampling method. Because different documents were accessed from the sources within the documents examined, snowball sampling method was used. These documents are listed in Appendix 1 in Appendices. The data were compiled manually.

In this context, the research questions of the study are as follows:

- **RQ1.** What are the strengths of smart factories?
- **RQ2.** What are the weaknesses of smart factories?
- **RQ3**. What are the opportunities that can be achieved with smart factory infrastructure?
- **RQ4.** What are the threats in the context of smart factory infrastructure?

4. Finding and Results

The results obtained from the analysed documents are as follows in the order of the research questions.

***RQ1*:** The strengths of smart factories are described below.

Forecasting consumer trends: Increased transparency in production processes (monitoring every production stage from procurement to the final product) makes the smart factory an agile structure that can adapt quickly to processes (Glavič, 2021). Thanks to the sensors that will be placed on the manufactured products, consumers' product usage data can be evaluated and adapted to customers' demands faster. In this way, more customised mass production can be possible.

Furthermore, the holistic manufacturing approach employed in smart factories extends beyond the agile manufacturing framework by incorporating sustainability practices. This comprehensive approach, designed for evaluating diverse production plans, aims to maximize output from available resources while minimizing energy consumption and environmental impact (Choi & Xirouchakis, 2014).

Labour, energy, material and waste cost savings: Within the scope of 3-D printers, smart supply chain, technology and employee collaboration, it may be possible to save costs in many areas from production to supply (Görçün, 2018; Akkad & Bányai, 2023; Shrouf, Ordieres & Miragliotta, 2014; Bhandari et al., 2023; Hossain & Khan, 2020). Planning the production phase in advance can minimise the loss in product quality and reduce the amount of waste during production.

Reduced stock storage: With the ability to accurately predict consumer demand, smart supply chain and 3-D printers, stock levels can be kept to a minimum (Paulsen, 2020; Kuznaz, Pfohl & Yahsi, 2015; Yu, Kim & Mathur, 2020).

Predictive maintenance: Thanks to the sensors in machinery and equipment, detailed information about the operation of machinery and equipment can be obtained. Possible malfunctions of the machine over time can be predicted before the malfunction occurs. For example, data such as an increase in noise level and temperature increase during the operation of the machine can be a harbinger of a possible malfunction in the machine. Replacing the equipment that may cause this failure within the scope of planned maintenance before the failure occurs can prevent capacity loss in production (Pech, Vrchota, & Bednář 2021; Zhong et al. 2023).

Minimising silos between departments within the factory: Thanks to the traceable infrastructure of smart factories, silos between departments can be eliminated. As a result of the collaboration between IT and operational technologies, stocks can be monitored regularly, unnecessary purchases can be prevented, and communication between departments can be coordinated more efficiently (Buntak, Kovačić & Martinčević, 2020; Inamdar, 2022).

Increasing brand equity: Since the brand image of a business with a smart factory infrastructure can be perceived positively by consumers, the business's brand value can increase (Ramaswamy & Ozcan, 2016).

Fast product production cycle: Thanks to the data/information cycle in smart factories, product design, engineering, production and quality processes such as product design, engineering, production and quality can be carried out in collaboration, which can shorten the product's delivery time (Tao et al., 2019).

Process duplication: Since the processes in smart factories are also generated in the cyber environment by utilising digital twin technology, it is easy to duplicate the processes to different structures (Corradini et al., 2023; Hänel et al., 2019).

Occupational health and safety: Employees' occupational health and safety can be maximised through smart factory applications (Taylor et al., 2020; Parmar et al., 2018).

RQ2**:** The weaknesses of smart factories are described below.

The process of smart factory transformation can be long and costly: Whether the transformation process is costly or not depends on the roadmap of the transformation. A roadmap can be prepared in accordance with the financial strength of the business. However, the transformation can be divided into small parts. As each part is completed, the transformation can be continued by evaluating what has been achieved (Narwane et al., 2022).

Failure to transform the entire factory into a smart factory: Failure to transform entire factories and processes into a smart factory infrastructure can lead to mismatch problems between the transformed and non-converted parts.

Resistance to Change: Possible employee resistance to smart factory transformation may prolong the transformation period (Thomas & Hardy, 2011; Tran, Pham & Bui, 2020; Kim & Lee, 2020; Marzano & Siguencia, 2021).

The situation of employees in the transformation process: Terminating the jobs of unqualified employees during the transformation process may cause unrest within the factory and for the employees' families. For this reason, preparing and qualifying unskilled employees for the transformation to a smart factory may be one of the most appropriate solutions (Háry, 2016; Schröder, 2016; Heynitz et al., 2016).

RQ3**:** Some of the opportunities that can be achieved with the smart factory are described below.

Environmental sustainability: By leveraging the data and information cycle, smart factories can manage processes such as production, procurement and inventory, minimising waste. This not only contributes to environmental sustainability but also enables cost savings (Ejsmont, Gladysz & Kluczek, 2020; Breque, De Nul & Petridis, 2021; Sajadieh, Son & Noh, 2022)

New business models: New business models can emerge with the data to be obtained from processes such as smart factories, smart logistics, smart procurement, etc. For example, white goods manufacturers can obtain customers' product usage preferences with the data they collect through the sensors they place in white goods. In this way, up-to-date work programs can be added to white goods. In this way, customer satisfaction levels can be increased (Lee & Jung, 2018).

Incentives: Smart factories are often considered within the scope of government incentives thanks to their contribution to environmental sustainability and the employment of qualified employees. Thanks to the incentives, the initial installation costs of smart factories can be mitigated.

Competitiveness: Smart factories not only enable flexibility in production processes but also enhance operational efficiency by facilitating the seamless integration of processes such as material supply, production, marketing, and customer support services. This integration provides businesses with a significant competitive advantage (Gramegna, Greggio & Bonollo, 2020). Furthermore, the incorporation of artificial intelligence technologies into these processes has the potential to elevate this advantage to a substantially higher level.

***RQ4*:** Some of the threats that may be experienced in the smart factory process are described below.

Cyber security threats: In order to ensure horizontal and vertical integration in smart factories, it is expected that the inside and the periphery of the factory will be networked. This may cause cyber security threats. Cybersecurity threats in operational technologies can cause major cybersecurity problems, including employee safety, stoppage of production processes, and disruptions in customer products. At the same time, there may be a risk of data and information related to processes related to IT technologies such as finance, procurement and logistics being compromised. It may even cause an increase in incidents such as corporate espionage (Kavallieratos & Katsikas, 2020; Flatt et al., 2016; Li et al., 2023; Hajj et al., 2020; Botta et al., 2023).

Cost Increases: After the COVID-19 pandemic, inflationary pressure and significant increases in raw material costs were experienced worldwide. Due to the increases in raw material costs, customers may postpone the purchase of a product. If the costs and customers' incomes do not increase at the same rate, the desired profit level may not be obtained from the products produced. Customers may postpone their purchasing decisions. This may lead to situations such as smart factory installation, update costs not being reflected on the products, or the profit obtained from the products not being able to cover these costs (Antony et al., 2023; Phuyal, Bista & Bista, 2020).

Government policies: Governments can withdraw the incentives they provide within the scope of the smart factory. By law, they can take some special measures for the products produced by the smart factory. Supportive policies are positive for the process. However, obstructive policies may involve high risks. For example, there may be a decrease in the employment rate of unqualified employees in the transition to smart factories. In the policies of governments, preventive attitudes towards the dismissal of unskilled personnel may impose extra costs on a business with a smart factory structure. However, social responsibilities should not be forgotten (Narwane et al., 2022; Matošková, Crhová & Gregar, 2023).

Demographic characteristics: Demographic characteristics of customers vary across countries. For example, Europe has an older population, while Asian countries have a younger population. The level of education in each country also varies. This change may change the customers' characteristics in purchasing and using the product. This situation may cause unmet customer expectations on the usage data planned to come from customers. For this reason, it would be more appropriate to plan the data targeted to be acquired from customers by taking into account the cultures of the countries (Correia, 2014; Fuller et al., 2020; Glavič, 2021).

Lack of skilled employees: There may be a lack of skilled employees in managing smart factory processes. It is thought that the minimum level in the evaluation of qualified personnel in smart factories means employees who understand the essence of smart factories and can adapt quickly to technology (Herrmann, 2018).

Technological infrastructure incompatibility of stakeholders in the external environment: Data owners in the external environment of the smart factory (such as customers, government and suppliers) may be reluctant to share data, and technological infrastructure incompatibilities may cause difficulties in obtaining data, especially from the external environment of the business. For example, the infrastructure of suppliers may not be suitable for generating data and sharing this data with the smart factory. Necessary consultancy can be provided to facilitate the adaptation of suppliers to the smart factory working infrastructure (Herrmann, 2018).

The strengths, weaknesses, opportunities and threats related to smart factories may vary by country, sector and time. In general, the results obtained in this study regarding smart factories' strengths, weaknesses, opportunities and threats are summarised in Table 1.

Table 1. SWOT Analysis

STRENGTHS

- Forecasting consumer trends
- Labour, energy, material and waste cost savings.
- Reduced stock storage.
- Predictive maintenance.
- Minimising silos between departments within the factory.
- Increased brand equity.
- Fast production cycle.
- Process duplication.
- Occupational health and safety

WEAKNESSES

- The process of smart factory transformation can be long and costly.
- Failure to transform the entire factory into a smart factory.
- Resistance to change.
- The situation of employees in the transformation process.

OPPORTUNITIES

- Environmental sustainability
- New business models.
- Incentives.
- Competitiveness

THREATS

- Cyber security threats.
- Cost Increases.
- Government Policies.
- Demographic characteristics
- Technological infrastructure incompatibility of stakeholders in the external environment of smart factory.
- Lack of skilled employee

5. Conclusion and Evaluation

Smart factories are next-generation factory solutions that enable business functions and processes to be carried out more efficiently within the scope of the data-knowledge cycle. However, it may be appropriate for businesses that want to establish a smart factory infrastructure or transform their existing infrastructure into a smart factory infrastructure to develop factory-specific solutions and get support from experts in their business while implementing this solution. The smart factory solution that every business and every sector needs may include data-knowledge cycle processes specific to the business or sector. Since smart factories do not only consist of technological devices, the data-knowledge cycle is very important. Technological devices may be the same for each sector. However, the analysis of data and knowledge to be acquired from these technological devices, sharing the resulting knowledge and other processes may differ according to businesses and sectors (Burke et al., 2017).

In this study, a SWOT analysis on smart factories was tried to be made. While making this analysis, data were collected and analysed with a general evaluation without sectoral distinction within the scope of smart factories. A business that wants to benefit from this analysis can update this analysis in accordance with its internal structure and sector. As a result, it may be useful for businesses that want to realise smart factory transformation to pay attention to the following items related to the smart factory

a. When designing smart factory processes, thinking big and doing things in small pieces (agile methodologies) can favour small and medium-sized businesses. Dividing the work into small parts can reduce the risk of error when the process is fed by feedback. In this way, the cost of a wrong application can be less.

b. Configuring smart factory processes requires ensuring the employment of qualified personnel. The presence of skilled workers can significantly contribute to economic growth. Dilber (2023), in the study Evaluation of the Sectoral Determinants of Economic Growth in Terms of the Labour Force, argues that there is a positive relationship between employment in the industrial sector and economic growth. Accordingly, smart factories that enable the employment of qualified personnel in the industrial sector are likely to positively impact economic growth.

c. In smart factories, cyber security should be considered as a whole, and studies should be carried out on the cyber security of both operational and information technologies.

d. While structuring the processes related to the smart factory, government incentives should be followed, and efforts should be made to benefit from these incentives. This can be a factor in reducing costs.

e. Data and knowledge can be obtained from the internal environment of the smart factory as desired. However, it should not be forgotten that different stakeholders control the external environment. Government policies, the status of suppliers, and customer profiles can complicate the process of acquiring data/knowledge from the external environment.

In this study, the advantages and opportunities, weaknesses and threats of smart factories were evaluated in general. Future studies on both country and sector basis may be useful for businesses that want to invest in smart factories.

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APPENDICES

Appendix 1. References of Samples

Title	**Reference**
Evolution and Current Challenges of Sustainable Consumption and Production	Glavič 2021
The Rise of Smart Factories in the Fourth Industrial Revolution and Its Impacts on the Textile Industry	Görçün 2018
Energy Consumption Optimization of Milk-Run-Based In-Plant Supply Solutions: An Industry 4.0 Approach	Akkad and Bányai 2023
Smart Factories in Industry 4.0: A Review of the Concept and of Energy Management Approached in Production Based on the Internet of Things Paradigm	Shrouf, Ordieres, and Miragliotta 2014
Evolution of Cyber-Physical-Human Water Systems: Challenges and Gaps	Bhandari et al. 2023
Water Footprint Management for Sustainable Growth in the Bangladesh Apparel Sector	Hossain and Khan, 2020
Predictive Maintenance and Intelligent Sensors in Smart Factory: Review	Pech, Vrchota, and Bednář, 2021
Overview of Predictive Maintenance Based on Digital Twin Technology	Zhong et al. 2023
Impact of Digital Transformation on Knowledge Management in Organization	Buntak, Kovačić, and Martinčević, 2020
Digital Twin-Driven Product Design, Manufacturing and Service with Big Data	Tao et al., 2018
Digital Twin-Driven Product Design Framework	Tao et al. 2019
Digital Transformation And Its Impact On Organisational Culture’	Inamdar, 2022
Executable Digital Process Twins: Towards the Enhancement of Process-Driven Systems	Corradini et al. 2023
Development of a Method to Determine Cutting Forces Based on Planning and Process Data as Contribution for the Creation of Digital Process Twins’	Hänel et al. 2019
Operator 4.0 or Maker 1.0? Exploring the Implications of Industrie 4.0 for Innovation, Safety and Quality of Work in Small Economies and Enterprises	Taylor et al. 2020
Smart Work-Assisting Gear’	Parmar et al., 2018
Examining Smart Manufacturing Challenges in the Context of Micro, Small and Medium Enterprises’. International Journal of Computer Integrated Manufacturing	Narwane et al., 2022
Reframing Resistance to Organizational Change	Thomas and Hardy, 2011
The Effect of Contextual Factors on Resistance to Change in Lean Transformation	Tran, Pham and Bui, 2020
Factors Affecting Technology Acceptance of Smart Factory	Kim and Lee 2020
Industry 4.0: Social Challenges and Risks	Marzano and Siguencia 2021
The Smart Factory and Its Risks	Herrmann 2018
Impact of Industry 4.0 on Sustainability-Bibliometric Literature Review	Ejsmont, Gladysz and Kluczek, 2020
Industry 5.0 Towards a Sustainable, Human-Centric and Resilient European Industry	Breque, De Nul and Petridis, 2021
A Conceptual Definition and Future Directions of Urban Smart Factory for Sustainable Manufacturing’	Sajadieh, Son and Noh, 2022

Competitive Strategy for Paradigm Shift in the Era of the Fourth Industrial Revolution: Focusing on Business Model Innovation	M. J. Lee and Jung, 2018
Managing Cyber Security Risks of the Cyber-Enabled Ship’. Journal of Marine Science and Engineering	Kavallieratos and Katsikas, 2020
Analysis of the Cyber-Security of Industry 4.0 Technologies Based on RAMI 4.0 and Identification of Requirements	Flatt et al., 2016
Cyber Security for Smart Factories	Hajj et al., 2020
A Critical Review of Cyber-Physical Security for Building Automation Systems	Li et al., 2023
Cyber Security of Robots: A Comprehensive Survey’. Intelligent Systems with Applications	Botta et al., 2023
Benefits, Challenges, Critical Success Factors and Motivations of Quality 4.0–A Qualitative Global Study’	Antony et al., 2023
Challenges, Opportunities and Future Directions of Smart Manufacturing: A State of Art Review	Phuyal, Bista and Bista, 2020
Examining Smart Manufacturing Challenges in the Context of Micro, Small and Medium Enterprises	Narwane et al., 2022
Why Manufacturers Need to Engage Employees When Implementing a Smart Factory: A Case Report from the Czech RepublicBy Focusing on the Human Element—Including Communicating the Vision and Plan to All Employees and Seeking Their Thoughts and Concerns—Manufacturers Can Make the Transition to a Smart Factory More Seamless.	Matošková, Crhová and Gregar, 2023
Future Possibilities, Social Challenges and Adaptation Requirements of Industrial Progress	Háry, 2016
The Challenges of Industry 4.0 for Small and Medium-Sized Enterprises	Schröder, 2016
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ETİK VE BİLİMSEL İLKELER SORUMLULUK BEYANI

Bu çalışmanın tüm hazırlanma süreçlerinde etik kurallara ve bilimsel atıf gösterme ilkelerine riayet edildiğini yazar beyan eder. Bu çalışma etik kurul izni gerektiren çalışma grubunda yer almamaktadır.

ARAŞTIRMACILARIN MAKALEYE KATKI ORANI BEYANI

1. yazar katkı oranı: %100