Conceptualizing the industry 4.0 adaptation for small and medium-sized enterprises & performance

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ABSTRACT

Information technology (IT), electronics, and digitalization have all contributed significantly to the emergence of the third Industrial Revolution. These innovations have paved the way for transformative technologies like the Internet of Things (IoT), Cyber Physical Systems (CPS), and the Internet of Services (IoS). Together, these elements constitute the foundation of Smart Factory, and they play a pivotal role in shaping the emergence of Industry 4.0. Industry 4.0 has a major influence on the industrial sector in industrialised countries, mostly by large firms. But, Small and medium sized enterprises (SMEs) find it challenging to replicate the same achievements. This paper explores the influence of emerging digital technology in Industry 4.0 on various factors that affect the adaptation of SMEs' organisational processes. Furthermore, developed a model to assess the organisation's performance, considering the mediating impact of the maturity score and the moderating influence of the industry type of the SME. The resource base view (RBV) theory and contingency theory are employed to develop the conceptual frame, and the maturity model is used to find the industry 4.0 maturity score. The paper makes an academic contribution by providing valuable insights to support future research on SMEs' transition towards digitalised processes and its impact on organisational performance.

Keywords: Operational Performance, Financial Performance, Industry 4.0, SME, Maturity Model, RBV and Contingency theory

INTRODUCTION

The dynamic environmental landscape presents significant challenges, driving businesses to invest heavily in sophisticated and integrated IT based solutions to enhance their competitiveness. Enterprises seek automated systems that facilitate collaboration and exchange of information regarding competitors, consumer trends, market dynamics, product delivery features, and technological advancements (Rajan & Baral, 2015). The industrial revolution evolved through three phases since the 1800s: Industry 1.0 utilised water and steam power, Industry 2.0 introduced assembly lines and mass production, while Industry 3.0 brought computer networks, robotics, and the Internet, revolutionising information management and sharing. (Gökalp et al., 2018). Additive manufacturing, AI, autonomous robots, CPS, IoT, big

data, augmented reality, and the smart factory idea are all examples of the coming digital technologies that are part of the "Industry 4.0" paradigm. Alternatively, Industry 4.0 can be seen as the progression of technology from embedded systems to CPS (Rojko, 2017). Industry 4.0 enables businesses to gain enhanced control by leveraging real time data, leading to improved productivity and streamlined processes. This powerful synergy fosters continuous growth, making it a driving force for industries that embrace these transformative technologies. SMEs are very important to the global economy because they help create jobs, reduce poverty, encourage business, and improve rural areas. In recent years, the business environment for SMEs has evolved, emphasising customer satisfaction and market flexibility. (Awan et al., 2021). Hence, SMEs are widely recognised as necessary for economic development. SMEs play an essential role in industrial value development and supplying large organisations (Müller et al., 2018). As a result of Industry 4.0, large organisations have new technology demands that must be fulfilled. However, most SMEs are not positioned to adopt this new technology (Yüksel, 2020a) and don't have fully understood the technology or digitalisation (Yüksel, 2020b). Moreover, they are uncertain about the capital required to purchase new technology and its effects on their business strategies (Schumacher et al., 2016a). Experts have identified key challenges in implementing Industry 4.0, including a lack of strategic direction, difficulty grasping complex concepts, uncertainty regarding benefits and costs, inability to assess readiness, and failure to evaluate capability. These challenges hinder businesses from embracing Industry 4.0 effectively (Schumacher et al., 2016a). Industrialised countries have established national strategies to support Industry 4.0 development, whereas developing countries rely on corporate-level initiatives without coordinated national policies. Developed nations prioritise comprehensive approaches while developing ones depend on individual company efforts for implementing Industry 4.0 technologies (Bogoviz et al., 2019). Similarly, the adaptation of Industry 4.0 systems in Asian countries manufacturing SMEs are less than 20% (Ghobakhloo & Ching, 2019) .

Recent studies reveal that SMEs have a low rate of digital adaptation in Industry 4.0, attributed to its complexity and unpredictability. Smaller businesses' risk aversion, resource limitations, and technical skill gaps pose challenges in adopting advanced technologies (Horváth & Szabó, 2019a). However, any industry lagging behind the industrial revolution has a significant risk of losing its competitive position and performance [12]. For Europe to reach its economic goals by 2030, it would require annual investments of 90 billion Euros in Industry 4.0 implementation [13]. (Geissbauer et al., 2016) A survey of over 2,000 senior executives from industrial product companies across 26 countries revealed that 56% of respondents anticipate

efficiency gains of over 20% in the next five years through Industry 4.0 adoption. Additionally, the introduction section in the literature emphasises that Industry 4.0 significantly enhances organisational performance. Hence, this research aims to address critical questions raised by SMEs regarding Industry 4.0, such as assessing their current situation, determining their level of transformation, identifying focus areas, and understanding how Industry 4.0 impacts financial and operational performance. The main objective is to develop a conceptual framework to evaluate SMEs' Industry 4.0 transformation and its effects on their financial and operational performance.

SMEs and Industry 4.0

Extensive studies on Industry 4.0 highlight the greater difficulties that SMEs commonly encounter in harnessing the potential advantages compared to larger organisations (Horváth & Szabó, 2019a). Also, emphasises customised production and manages the full product lifecycle value chain (Vaidya et al., 2018). Industry 4.0 technology implementation necessitates the integration of contemporary innovations and existing legacy systems, creating the essential connectivity and intelligence required for optimal functionality of front-end technologies (Benitez et al., 2020). However, (Estensoro et al., 2022) emphasise that the implementation of Industry 4.0 is adequate to achieve a sustainable competitive advantage in SMEs.

SMEs can classify Industry 4.0 technologies into two tiers: first-tier and second-tier technologies [15]. SMEs may independently acquire and utilise first-tier technology like 3D printers. The integration of several first-tier technologies, such as data collecting systems and machine learning, gives rise to second-tier technologies like industrial IoT and CPS. (Ghobakhloo & Ching, 2019). (Agostini & Nosella, 2019b) investigated the essential correlation between advanced manufacturing technologies (AMTs) with Industry 4.0. These AMTs play a critical role in enabling the successful implementation of Industry 4.0 technologies by SMEs. Furthermore, computer aided design and engineering, digital factory floor, enterprise support operations, and supply chain integration technology are the four groups of Industry 4.0 technologies that have been recommended for SMEs (Bosman et al., 2019).

Existing research highlights multiple categories for Industry 4.0 technologies, but SMEs' adoption rate has been significantly low. Although many SMEs benefit from basic digital technologies, the adoption of current Industry 4.0 devices remains low across segments. For instance, less than 20% of high-tech Czech SMEs use advanced technologies like 3D printing,

virtual reality, or autonomous vehicles (Pech & Vrchota, 2020). European SMEs face similar challenges (Agostini & Nosella, 2019a). Moreover, South Korean manufacturing SMEs (Won & Park, 2020), Norwegian manufacturing SMEs (Buer, Strandhagen, et al., 2021) , and Australian SMEs (Hopkins, 2021) are also at an equivalent level.

SMEs face challenges in developing growth strategies due to limited technological knowledge, inadequate R&D, and insufficient financial investment for technology adoption(Al Bulushi & Bagum, 2017). Policymakers and industry associations express concerns that the absence of defined frameworks and standards leaves SMEs lagging in Industry 4.0 implementation, lacking the necessary resources(Khanzode et al., 2021). Thus, it is widely acknowledged among scholars that most SMEs remain in the early adoption phase and have yet to implement advanced Industry 4.0 technologies (Chatterjee et al., 2021; Maisiri et al., 2021).

Industry 4.0 and Organisation Performance

Over the past few years, a new research domain has emerged dedicated to examining the effects of Industry 4.0 on organisational performance (Kohtamäki et al., 2019). According to (Bruck et al., 2018), the quantity and extensive utilisation of Industry 4.0 technologies within a company have a positive influence on creating opportunities. However, there are changes in outcomes with real performance rather than the expected indicators. As per (Szász et al., 2021), Industry 4.0, encompassing advanced technologies linked to the future's smart factory and the trend towards automation and robotisation, significantly impacts cost, quality, delivery, and flexibility performances. (Tortorella et al., 2019) made a difference between the two types of Industry 4.0 technologies. Technologies supporting manufacturing practices positively impact operational performance indicators, while those supporting product and service development have no direct impact.

Furthermore, the study conducted by (Swierczek, 2022) revealed that the emergence of supply chains acts as a complete mediator in the relationship between Industry 4.0 technologies and process performance. Additionally, there exists a positive correlation between supply chains and organisational performance. Similarly, (Wankhede & Vinodh, 2023) indicated that Industry 4.0 moderately relates to the organisation's productivity performance. According to (Antony et al., 2021) early adopters of Industry 4.0 outperform late adopters in operational, financial, environmental, and social aspects. (Cho et al., 2022) reveals that Industry 4.0 technologies, such as technology sensing and responding capability, have positive effects on exploratory and exploitative innovativeness, leading to improved new product performance. Likewise, (Mubarak et al., 2021) emphasises the positive impact of Industry 4.0 on open

innovation and green innovation performance. As a result, the research incorporates the Industry 4.0 maturity score as a mediator of organisation performance.

THEORETICAL BACKGROUND

Globalisation and competitiveness have significantly influenced organisations' decisions to use technology solutions to manage their day-to-day business requirements (Wieder et al., 2006; Yurtyapan & Aydemir, 2021). As a result, these solutions can be found in computerised business processes, well-organised accounting systems, and other projects that could help a business improve its performance and capabilities (Haddara et al., 2022). Among all technologies, Industry 4.0 strongly emphasises creating customised products tailored to meet specific customer requirements. It represents a new paradigm in planning, implementing, and controlling the entire value chain of the product (Lasi et al., 2014).

Using the TOE framework (which stands for technology, organisation, and environment), researchers (Hirschheim, 2007) have studied how organisations embrace new technologies. Their study revealed that multiple factors play a role in influencing the adoption of AI among Swedish manufacturing SMEs. Another study (Trstenjak et al., 2019)looked at the impact of Industry 4.0 on manufacturing and service facilities by using four MCDM techniques (analytical hierarchy process (AHP), PROMETHEE, ELECTRE, and TOPSIS). (Sari & Santoso, 2020) conduct a study to examine the preparations of SMEs in Indonesia using the SEM-multigroup test with a sample size of 300 businesses. The theory of reasoned action (TRA) was used in(Widayani et al., 2020) to evaluate the readiness and capability of SMEs from an Industry 4.0 perspective. Moreover, (Jang et al., 2022b), employed the resource-based view (RBV) and contingency theory to analyse the SME's performance by evaluating Industry 4.0 maturity levels in Korea. Similarly, (Wang et al., 2020) evaluate the logistics innovation capability in the Industry 4.0 era by employing the RBV and Contingency theories. Hence researchers employed above discussed theories and models to evaluate industry 4.0 with SMEs behaviours.

Resource Based View Theory and Contingency Theory

The RBV theory is the most influential perspective on organisational strategy. According to RBV, a company's competitive advantage rests on its resources, both tangible (such as its physical assets) and intangible (such as its knowledge, skills, and capabilities). The contingency theory contends that the efficacy of a company's strategy is dependent on the environment in which it operates (Barney, 1991). The RBV theory indicates that a firm's

resources are skills, tech, capabilities, and infrastructure. Capabilities are complex skills and knowledge used through processes to support actions and asset utilisation (Day, 1994; Hafeez et al., 2002). Thus, the adoption of Industry 4.0 is expected to enable companies to elevate manufacturing capacities and potentially enhance overall performance. Also, Industry 4.0 technologies can offer businesses novel competitive advantages by lowering production costs, shortening delivery times, enhancing product quality, and improving overall flexibility [54],[55]. Low-tech SMEs benefit from Industry 4.0 adoption, reducing labor costs and improving quality. RBV suggests Industry 4.0 systems as valuable assets enhancing productivity. Increasing Industry 4.0 maturity boosts SME efficiency and competitiveness(Mittal et al., 2020). Therefore, a company's resource value and competitive advantage depend on the factors of the business environment in which it performs. According to contingency theory, organisations should maximise and improve their resources and skills to maintain the uniqueness of their business environments (Zheng et al., 2021). According to this theory, organisations must achieve high performance by maintaining and balancing their structures and contextual factors (Donaldson, 2001). The contingency method is commonly used to study contextual factors, manufacturing practices, and performance results to determine the settings in which adopted practices are effective (Sousa & Voss, 2008). So, this study uses the contingency theory to explain how the deployment of Industry 4.0 can enhance the performance of SMEs.

The study, which was conducted using a combination of RBV and contingency theory, can expand on existing conceptual studies related to Industry 4.0 and improve current empirical studies. It showed that organisational learning capabilities mediated the relationship between Industry 4.0 technology and organisational performance (Tortorella et al., 2020). Also, this combination is used to discover lean manufacturing and organisation performance with mediating effect of Industry 4.0 technology (Kamble et al., 2020). Similarly, both theories are employed to evaluate the improvement of the operational performance and supply chain capabilities with the adaptation of Industry 4.0 technology (Chauhan et al., 2021). Hence we can utilise the combination of RBV and contingency theory to evaluate organisation performance with the mediation effect of industry 4.0 technology.

Maturity Model

Maturity is defined as the point at which one is completely grown or matured. (Paulk et al., 1993) employed the maturity model to evaluate the software development capabilities. These

methods have been widely recognised in many different kinds of areas. The maturity model can be applied in several domains, such as assessing IT capabilities, ensuring top management desition, evaluating the new improvement, overseeing project management, developing cooperative desition, and enhancing skill development (De Bruin et al., 2005). Similarly (Hankel & Rexroth, 2015), the maturity model is applied to evaluate the Industry 4.0 adaptation level. Also, researchers have produced models for determining Industry 4.0 readiness as well as proposals and designs for Industry 4.0 roadmaps (Pacchini et al., 2019). (Basl & Doucek, 2019) discussed the maturity score that may be used to determine an SME's readiness for implementing Industry 4.0 technology and digital/smart automation techniques or current technology level. The assessment of maturity was derived by considering various organizational aspects in practice, and the validity of the index was verified through both qualitative and quantitative methodologies.

Hence, maturity models serve as valuable tools for identifying and assessing a company's level of maturity within a specific field or method concerning its progress towards a future objective (Ávila Bohórquez & Gil Herrera, 2022). Within a maturity model, a designated level acts as the initial stage, providing a foundation from which progression to higher levels of maturity can be strategically planned and executed. The primary aim of maturity models is to quantify and gauge the efficacy of undertaken activities, fostering their measurability and gradual advancement (Mittal et al., 2018). The above literature suggests using maturity models to evaluate Industry 4.0 adaptation in SMEs. These conceptual structures define maturity levels, guide procedures for future outcomes, and classify capabilities for internal and competitor analysis, as well as benchmarking.

As per the above theoretical exploration, the following theoretical model is employed to develop the conceptual framework and presented in Figure 1.

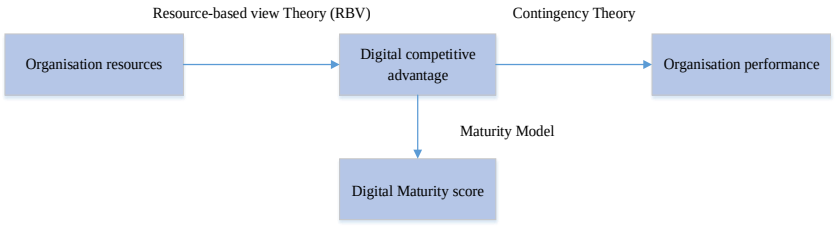

Figure 1: Proposed theoretical framework

Proposed Conceptual Framework

The RBV is an essential perspective in organisational strategy, with the literature and

theoretical framework highlighting the importance of both physical and skill resources in achieving a competitive benefit. RBV focuses on firms' distinctiveness, strategic resource utilisation, and adaptation to business environments.(Lockett & Thompson, 2004). However, the financial support of the technology and management IT knowledge influence the leverage of the organisation's digital competitive advantage (Rahimli, 2012; Zhang & Lv, 2021). Furthermore, the organisation's agility positively impacts the sustainable development of the organisation and digital innovations (El-Khalil & Mezher, 2020; Sun et al., 2022; Attafar et al., 2013). Similarly, business competitiveness influences the organisation's digital competitiveness as well as new digital business models (Sunigovets, 2019). The study selected independent variables categorised as "management IT knowledge" and "financial support on technology" under management-related factors, and "organisation agility" and "business competitiveness" under business factors. The dependent variables are "financial performance" and "operation performance" based on contingency theory's focus on maximising resources and capabilities to match specific business contexts.

As per the literature given in the introduction, SMEs generally have less knowledge of Industry 4.0 technology. Hence, SMEs need to use proper assessment tools to evaluate their current position at the technology level (Rauch et al., 2020). The maturity model is a suitable method that can be employed to evaluate companies and organisations. Because it provides a clearer picture of the steps still required to get the desired outcomes. (Pöppelbuß & Röglinger, 2011). In business, "maturity" usually indicates how far along in accurate execution the organisation is in connection with whatever it aims to analyse or appraise. Both quantitative and qualitative maturity assessments are possible, employing criteria based on individual or group factors, respectively (Schumacher et al., 2016b). Hence, we selected the "Industry 4.0 maturity score" as the mediator of the conceptual framework.

The engagement and success of Industry 4.0 may vary depending on the technological environment. High-tech industries with rapidly changing production technologies differ from low-tech industries with slower changes(Ko et al., 2020). High-tech manufacturing organisations tend to be more dynamic and information-intensive (Yang & Kang, 2008). Collaborations among machines, humans, and processes are crucial for optimising Industry 4.0 systems (Won & Park, 2020). Hence we selected the industry types as the moderator variable of industry performance in the conceptual framework.

The proposed conceptual framework is shown in Figure 2, according to the above description.

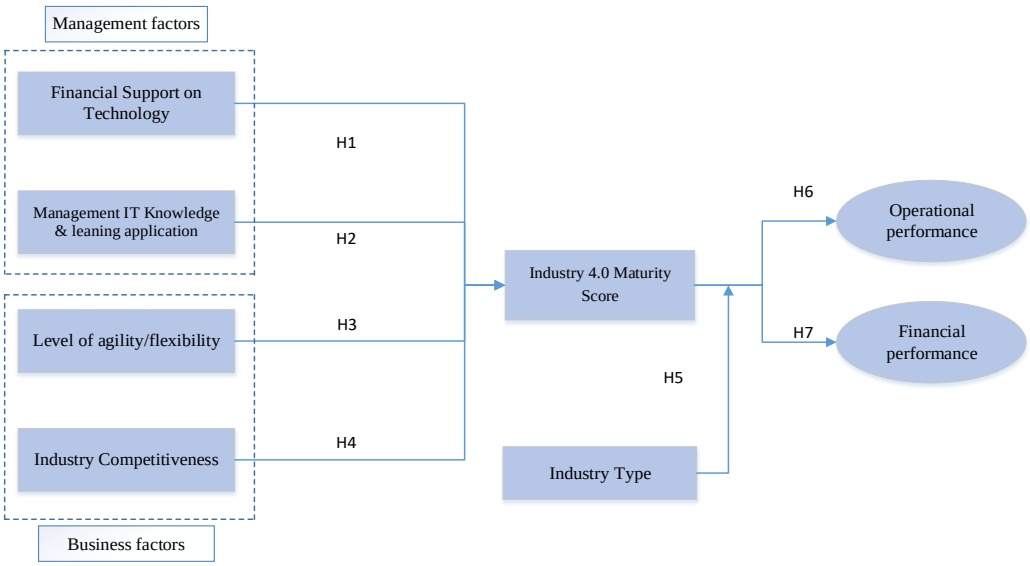

Figure 2: Proposed conceptual framework

Hypothesis development

Research hypotheses are developed based on the research questions, and the following research questions can be developed from the above conceptual framework. These questions address the transformation of SMEs into Industry 4.0, the impact of Industry 4.0 transformation on financial and operational performance, and whether the industry type influences the effects of Industry 4.0 transformation on financial and operational performance. The researcher expected to develop the following hypothesis to achieve the above questions.

Financial Support on Technology (H1)

The organisation's financial capability is an important factor in adopting modern technology (Hajoary, 2020). The availability of financial resources is an essential aspect of any business. Investments and the return on investments are very important to all businesses (Jasra et al., 2011). SMEs are typically owner-centred or family-owned organisations with limited financial resources. Hence, they have obstacles to adopting new technology or enhancing the Industry 4.0 maturity ladder (Martinsuo & Luomaranta, 2018). However, several authors indicated that investment in the R&D has more probability to the adaptation of Industry 4.0 application than the size of the organisation (Buer, Semini, et al., 2021). Furthermore, new developments in Industry 4.0 offer significant opportunities for SMEs (Haug et al., 2023). Hence, the organisation's Industry 4.0 maturity score is most significantly influenced by financial support for technology.

Management IT Knowledge and Learning Application (H2)

(Jain & Ajmera, 2020) state that the most important considerations for implementing Industry 4.0 are the employees' experience, knowledge, and access to training opportunities. Similarly, (Horváth & Szabó, 2019a) discovered that effective management and control are the major motivators for developing Industry 4.0. However, a significant obstacle to successfully adopting Industry 4.0 is the deficiency in capable management, capable employees and their behaviour to adup the new environment (Mittal et al., 2018). Hence, for organisations to effectively implement Industry 4.0 technologies, they need to conduct effective learning programs and develop new training techniques that enable the improvement of employee skills (Kiel et al., 2017). Hence management IT knowledge and learning application is significantly influencing when implantation Industry 4.0.

Level of Agility / Flexibility (H3)

Agility is the capacity of a system to adjust to evolving demands through the substitution or enhancement of individual processes facilitated by specified software and hardware interfaces. (Hermann et al., 2015). Incorporating organisational agility is a fundamental guiding principle for the successful implementation of Industry 4.0. Embracing agile and flexible frameworks is imperative to effectively address the challenges posed by Industry 4.0 and sustain adaptability in this dynamic environment (Veile et al., 2020). Properly constructed organisational structures and procedures that are more important in a dynamic atmosphere. (Horváth & Szabó, 2019b). Industry 4.0 gives the industry several opportunities that will help improve organisational agility. Also, organisational agility is a key part of dealing with changes in circumstances like Industry 4.0 (Matthiae & Richter, 2018). Hence the level of agility/flexibility is significantly influenced when the implantation of Industry 4.0

Industry Competitiveness (H4)

Competitive pressures regularly force organisations to seek innovative approaches that enhance operational efficiency and drive productivity growth (Themistocleous et al., 2004). Most organisations embrace their rival's technologies due to pressure from their business partners and competitors (Teo, 2007). According to (Horváth & Szabó, 2019b), market competition and rivalry are essential factors. Leveraging innovations rooted in Industry 4.0 technologies can empower companies to expand their market presence and gain a distinctive competitive edge. There is room for innovation in both business models and the value proposition. Thus, by strategically investing in emerging digital technologies, businesses can enhance their

competitive advantage and secure unparalleled positions in their respective markets (Hortoványi, 2016). Therefore, SMEs have embraced Industry 4.0 technology in order to make better, faster business decisions in more competitive markets. (Boonsiritomachai et al., 2016). Hence Industry Competitiveness is significantly influenced when the implantation of Industry 4.0.

Industry Type (H5)

The business plan of a company is based on situations and contexts that must change all the time for its sustainability (Egfjord & Sund, 2020). Because various industries operate in different technological contexts, this can have an impact on a company's capacity to innovate and its approach to acquiring new knowledge and resources (Chun et al., 2015). There are significant differences between the high-tech and low-tech industries (Lin et al., 2006). Technologically advanced enterprises produce advanced technology and do extensive R&D. Conversely, low-tech businesses usually work where technology changes slowly(Hirsch-Kreinsen, 2008). Hence, the industry types moderately affect Industry 4.0 and organisation performance.

Industry 4.0 Maturity Score and Organisation Operational Performance (H6)

SMEs would benefit financially and operationally from adopting Industry 4.0 technology, and this will encourage businesses to shift their focus to the consumer (Mittal et al., 2020). Similarly, (Tao et al., 2018) described that Industry 4.0 enables customising products based on individual needs by leveraging big data analytics for measuring customer demands and preferences. This facilitates mass customisation, reduces manufacturing costs, and enhances flexibility to meet changing customer requirements (Lu et al., 2020). Manufacturing waste may be minimised, and resource value can be maximised with the help of Industry 4.0 systems. Businesses may reduce the risks associated with deploying resources by creating, testing, and analysing virtualised models of industrial assets in action. (Parhi et al., 2021). Additionally, organisation management must make various decisions that demand huge amounts of data and complicated computations. Cloud computing can facilitate complicated decision-making and store enormous volumes of data on cloud servers (Xu et al., 2018). Furthermore, increased accuracy in processing, decreased costs, and real-time data collection are just some of the benefits provided by IoT (Rajput & Singh, 2018). Businesses can reduce waste and increase productivity by remotely monitoring and controlling these processes. Also, automation and industrial robots can reduce the number of mistakes and help tasks be carried out quickly,

repeatedly, and accurately (Ghobakhloo, 2018). Hence, Industry 4.0 technologies is significnly influence the operational performance.

Industry 4.0 Maturity Score and Organisation Financial Performance. (H7)

The literature discussed in 4.1.6 shows that the adaptation of Industry 4.0 is beneficial to encouraging the organisation's operational and financial performance. However, cost of operation and maintenance, quality, delivery, lead time, and flexibility are the desired criteria for operational performance. As such, it could positively impact the business performance (Büyüközkan et al., 2015). This may be linked to the reduction in inventory and materials expenses, as well as the enhancement of labour efficiency. Also, reducing sales returns can enhance sales productivity (Altuk & Kablan, 2020). Additionally, Ghobakhloo (2020) emphasises that digitisation will contribute to the creation of economic advantages over time with the implementation of Industry 4.0 across the board in the business ecosystem. Hence, Industry 4.0 technologies significantly influence financial performance.

RESEARCH METHOD

Saunders et al. (2016) grouped research methods into quantitative, qualitative, simple or complex combinations and mono methods. Qualitative research uses numbers and mathematics but also has a lot of descriptive data. Quantitative or qualitative based on data research is known as the "mono method". The "mixed methods" and "multi-method" methods use both qualitative and quantitative methods, even if one is primary and the other is auxiliary or supplementary, to achieve various objectives and overcome the constraints of a single method. However, qualitative approaches typically use open-ended methods, resulting in a time-consuming process of translating and analysing data (Powelson, 2012). Hence, the quantitative approach is recommended to find the research objective.

CONCLUSION

The latest innovations in Industry 4.0 present chances for businesses to improve their operations and this trend can no longer be ignored. This strategy might be especially useful for SMEs operating in challenging conditions. (Peillon & Dubruc, 2019). While SMEs may be successful with their present approaches, they may be hindered from expanding further and may fall behind their global market rivals if they do not adopt Industry 4.0 technologies. This research aims to develop the conceptual framework to evaluate whether the SMEs are transforming into Industry 4.0, how the Industry 4.0 transformation affects financial and

operational performance, and how the Industry 4.0 transformation affects financial and operational performance. The Industry 4.0 maturity model, RBV and contingency theory are employed to develop the above framework. Based on the literature, we selected the independent variables under two categories. Existing "management IT knowledge" and "financial support on technology" are taken under the management-related independent variables. Similarly, "organisation agility" and "business competitiveness "are taken under the business factors. Also, the organisation's "financial performance" and "operation performance" are selected as the dependent variables in the conceptual framework. Hence this framework can be used for academically by supporting future research investigating SMEs in planning conversion towards digitalised processes and how it affects the organisation's performance. Also, this research findings can serve as a foundation for constructing a more accurate conceptual framework in future investigations.

REFERENCE

Agostini, L., & Nosella, A. (2019a). The adoption of Industry 4.0 technologies in SMEs: Results of an international study. *Management Decision*, *58*(4), 625–643. https://doi.org/10.1108/MD-09-2018-0973

Agostini, L., & Nosella, A. (2019b). "The adoption of Industry 4.0 technologies in SMEs: Results of an international study" Management Decision 58 (4): 625–643. Doi:10.1108/MD-09- 2018-0973. *Management Decision*, *58*(4), Article 4. https://doi.org/10.1108/MD-09-2018-0973

Al Bulushi, B. H. S., & Bagum, S. (2017). Growth strategies of sme in Oman-Issues and challenges. *International Journal of Small Business and Entrepreneurship Research*, *5*(2), 21–61.

Altuk, V. E., & Kablan, A. (2020). A Critical Approach to Accounting in the Digital Era: Assessment of the Impacts of Industry 4.0 on Financials. In U. Hacioglu (Ed.), *Digital Business Strategies in Blockchain Ecosystems* (pp. 439–456). Springer International Publishing. https://doi.org/10.1007/978-3-030-29739-8_21

Antony, J., Sony, M., McDermott, O., Furterer, S., & Pepper, M. (2021). How does performance vary between early and late adopters of Industry 4.0? A qualitative viewpoint. *International Journal of Quality & Reliability Management*, *40*(1), 1–24. https://doi.org/10.1108/IJQRM-05-2021-0134

Attafar, A., Barzoki, A. S., & Radmehr, R. (2013). *Determine the Level of Maturity of Organization and Organizational Agility in Industrial Companies (Case of Study: Fakour Industrial Company)* (Iran). https://www.semanticscholar.org/paper/Determine-the-Level-of-Maturity-of-Organization-and-Attafar-Barzoki/09c800d6bf27adb5f31d92147c5e197266c9b114

Ávila Bohórquez, J. H., & Gil Herrera, R. de J. (2022). Proposal and validation of an industry 4.0 maturity model for SMEs. *Journal of Industrial Engineering and Management*, *15*(3), 433–454.

Awan, M., Ullah, N., Ali, S., Abbasi, I. A., Hassan, M. S., Khattak, H., & Huang, J. (2021). An Empirical Investigation of the Challenges of Cloud-Based ERP Adoption in Pakistani SMEs. *Scientific Programming*, *2021*, 1–8. https://doi.org/10.1155/2021/5547237

Barney, J. (1991). Firm resources and sustained competitive advantage. *Journal of Management*, *17*(1), 99–120.

Basl, J., & Doucek, P. (2019). A metamodel for evaluating enterprise readiness in the context of Industry 4.0. *Information*, *10*(3), 89.

Benitez, G. B., Ayala, N. F., & Frank, A. G. (2020). Industry 4.0 innovation ecosystems: An evolutionary perspective on value cocreation. *International Journal of Production Economics*, *228*, 107735.

Bogoviz, A. V., Osipov, V. S., Chistyakova, M. K., & Borisov, M. Y. (2019). Comparative analysis of formation of industry 4.0 in developed and developing countries. In *Industry 4.0: Industrial Revolution of the 21st Century* (pp. 155–164). Springer.

Boonsiritomachai, W., McGrath, G. M., & Burgess, S. (2016). Exploring business intelligence and its depth of maturity in Thai SMEs. *Cogent Business & Management*, *3*(1), 1220663. https://doi.org/10.1080/23311975.2016.1220663

Bosman, L., Hartman, N., & Sutherland, J. (2019). How manufacturing firm characteristics can influence decision making for investing in Industry 4.0 technologies. *Journal of Manufacturing Technology Management*, *31*(5), 1117–1141. https://doi.org/10.1108/JMTM-09-2018-0283

Bruck, B. P., Cordeau, J.-F., & Iori, M. (2018). A practical time slot management and routing problem for attended home services. *Omega*, *81*, 208–219.

Buer, S.-V., Semini, M., Strandhagen, J. O., & Sgarbossa, F. (2021). The complementary effect of lean manufacturing and digitalisation on operational performance. *International Journal of Production Research*, *59*(7), 1976–1992. https://doi.org/10.1080/00207543.2020.1790684

Buer, S.-V., Strandhagen, J. W., Semini, M., & Strandhagen, J. O. (2021). The digitalization of manufacturing: Investigating the impact of production environment and company size. *Journal of Manufacturing Technology Management*, *32*(3), 621–645.

Büyüközkan, G., Kayakutlu, G., & Karakadılar, İ. S. (2015). Assessment of lean manufacturing effect on business performance using Bayesian Belief Networks. *Expert Systems with Applications*, *42*(19), 6539–6551.

Calabrese, A., Levialdi Ghiron, N., & Tiburzi, L. (2021). 'Evolutions' and 'revolutions' in manufacturers' implementation of industry 4.0: A literature review, a multiple case study, and a conceptual framework. *Production Planning & Control*, *32*(3), 213–227.

Chatterjee, S., Rana, N. P., Dwivedi, Y. K., & Baabdullah, A. M. (2021). Understanding AI adoption in manufacturing and production firms using an integrated TAM-TOE model. *Technological Forecasting and Social Change*, *170*, 120880.

Chauhan, C., Singh, A., & Luthra, S. (2021). Barriers to industry 4.0 adoption and its performance implications: An empirical investigation of emerging economy. *Journal of Cleaner Production*, *285*, 124809.

Cho, J., Jeong, I., Kim, E., & Cho, H. E. (2022). Seizing the moment in the flux of Industry 4.0: Technological opportunism, innovativeness and new product performance in international markets. *European Journal of Innovation Management*, *ahead-of-print*(ahead-of-print). https://doi.org/10.1108/EJIM-04-2022-0181

Chun, D., Chung, Y., Woo, C., Seo, H., & Ko, H. (2015). Labor union effects on innovation and commercialization productivity: An integrated propensity score matching and two-stage data envelopment analysis. *Sustainability*, *7*(5), 5120–5138.

Day, G. S. (1994). The capabilities of market-driven organizations. *Journal of Marketing*, *58*(4), 37–52.

De Bruin, T., Rosemann, M., Freeze, R., & Kaulkarni, U. (2005). Understanding the main phases of developing a maturity assessment model. *Australasian Conference on Information Systems (ACIS)*, 8–19.

Donaldson. (2001). *The contingency theory of organizations*. Sage.

Egfjord, K. F.-H., & Sund, K. J. (2020). Do you see what I see? How differing perceptions of the environment can hinder radical business model innovation. *Technological Forecasting and Social Change*, *150*, 119787.

El-Khalil, R., & Mezher, M. A. (2020). The mediating impact of sustainability on the relationship between agility and operational performance. *Operations Research Perspectives*, *7*, 100171. https://doi.org/10.1016/j.orp.2020.100171

Estensoro, M., Larrea, M., Müller, J. M., & Sisti, E. (2022). A resource-based view on SMEs regarding the transition to more sophisticated stages of Industry 4.0. *European Management Journal*, *40*(5), 778–792.

Geissbauer, R., Vedso, J., & Schrauf, S. (2016). *Industry 4.0: Building the digital enterprise*.

Ghobakhloo, M. (2018). The future of manufacturing industry: A strategic roadmap toward Industry 4.0. *Journal of Manufacturing Technology Management*, *29*(6), 910–936.

Ghobakhloo, M. (2020). Industry 4.0, digitization, and opportunities for sustainability. *Journal of Cleaner Production*, *252*, 119869.

Ghobakhloo, M., & Ching, N. T. (2019). Adoption of digital technologies of smart manufacturing in SMEs. *Journal of Industrial Information Integration*, *16*, 100107.

Gökalp, E., Gökalp, M. O., & Eren, P. E. (2018). Industry 4.0 revolution in clothing and apparel factories: Apparel 4.0. *Industry*, *4*, 169–183.

Haddara, M., Gøthesen, S., & Langseth, M. (2022). Challenges of Cloud-ERP Adoptions in SMEs. *Procedia Computer Science*, *196*, 973–981. https://doi.org/10.1016/j.procs.2021.12.099

Hafeez, K., Zhang, Y., & Malak, N. (2002). Determining key capabilities of a firm using analytic hierarchy process. *International Journal of Production Economics*, *76*(1), 39–51.

Hajoary, P. K. (2020). Industry 4.0 maturity and readiness models: A systematic literature review and future framework. *International Journal of Innovation and Technology Management*, *17*(07), 2030005.

Hankel, M., & Rexroth, B. (2015). The reference architectural model industrie 4.0 (rami 4.0). *Zvei*, *2*(2), 4–9.

Haug, A., Adsbøll Wickstrøm, K., Stentoft, J., & Philipsen, K. (2023). The impact of information technology on product innovation in SMEs: The role of technological orientation. *Journal of Small Business Management*, *61*(2), 384–410. https://doi.org/10.1080/00472778.2020.1793550

Hermann, M., Pentek, T., & Otto, B. (2015). Design principles for Industrie 4.0 scenarios: A literature review. *Technische Universität Dortmund, Dortmund*, *45*.

Hirschheim, R. (2007). Introduction to the Special Issue on" Quo Vadis TAM-Issues and Reflections on Technology Acceptance Research". *Journal of the Association for Information Systems*, *8*(4), 9.

Hirsch-Kreinsen, H. (2008). " Low-technology": A forgotten sector in innovation policy. *Journal of Technology Management & Innovation*, *3*(3), 11–20.

Hopkins, J. L. (2021). An investigation into emerging industry 4.0 technologies as drivers of supply chain innovation in Australia. *Computers in Industry*, *125*, 103323.

Hortoványi, L. (2016). The dynamic nature of competitive advantage of the firm. *Advances in Economics and Business*, *4*(11), 624–629.

Horváth, D., & Szabó, R. Z. (2019a). Driving forces and barriers of Industry 4.0: Do multinational and small and medium-sized companies have equal opportunities? *Technological Forecasting and Social Change*, *146*, 119–132.

Horváth, D., & Szabó, R. Z. (2019b). Driving forces and barriers of Industry 4.0: Do multinational and small and medium-sized companies have equal opportunities? *Technological Forecasting and Social Change*, *146*, 119–132.

Jain, V., & Ajmera, P. (2020). Modelling the enablers of industry 4.0 in the Indian manufacturing industry. *International Journal of Productivity and Performance Management*, *70*(6), 1233–1262. https://doi.org/10.1108/IJPPM-07-2019-0317

Jang, S., Chung, Y., & Son, H. (2022a). Are smart manufacturing systems beneficial for all SMEs? Evidence from Korea. *Management Decision*, *60*(6), 1719–1743. https://doi.org/10.1108/MD-12-2020-1632

Jang, S., Chung, Y., & Son, H. (2022b). Are smart manufacturing systems beneficial for all SMEs? Evidence from Korea. *Management Decision*, *60*(6), 1719–1743. https://doi.org/10.1108/MD-12-2020-1632

Jasra, J., Hunjra, A. I., Rehman, A. U., Azam, R. I., & Khan, M. A. (2011). Determinants of business success of small and medium enterprises. *International Journal of Business and Social Science*, *2*(20).

Kamble, S., Gunasekaran, A., & Dhone, N. C. (2020). Industry 4.0 and lean manufacturing practices for sustainable organisational performance in Indian manufacturing companies. *International Journal of Production Research*, *58*(5), 1319–1337. https://doi.org/10.1080/00207543.2019.1630772

Khanzode, A. G., Sarma, P. R. S., Mangla, S. K., & Yuan, H. (2021). Modeling the Industry 4.0 adoption for sustainable production in Micro, Small & Medium Enterprises. *Journal of Cleaner Production*, *279*, 123489.

Kiel, D., Müller, J. M., Arnold, C., & Voigt, K.-I. (2017). Sustainable industrial value creation: Benefits and challenges of industry 4.0. *International Journal of Innovation Management*, *21*(08), 1740015.

Ko, W. L., Kim, S. Y., Lee, J.-H., & Song, T. H. (2020). The effects of strategic alliance emphasis and marketing efficiency on firm value under different technological environments. *Journal of Business Research*, *120*, 453–461.

Kohtamäki, M., Parida, V., Oghazi, P., Gebauer, H., & Baines, T. (2019). Digital servitization business models in ecosystems: A theory of the firm. *Journal of Business Research*, *104*, 380–392.

Lasi, H., Fettke, P., Kemper, H.-G., Feld, T., & Hoffmann, M. (2014). Industry 4.0. *Business & Information Systems Engineering*, *6*(4), 239–242.

Lin, B.-W., Lee, Y., & Hung, S.-C. (2006). R&D intensity and commercialization orientation effects on financial performance. *Journal of Business Research*, *59*(6), 679–685.

Lockett, A., & Thompson, S. (2004). Edith Penrose's contributions to the resource-based view: An alternative perspective. *Journal of Management Studies*, *41*(1), 193–203.

Lu, Y., Xu, X., & Wang, L. (2020). Smart manufacturing process and system automation–a critical review of the standards and envisioned scenarios. *Journal of Manufacturing Systems*, *56*, 312–325.

Maisiri, W., van Dyk, L., & Coeztee, R. (2021). Factors that inhibit sustainable adoption of Industry 4.0 in the South African manufacturing industry. *Sustainability*, *13*(3), 1013.

Martinsuo, M., & Luomaranta, T. (2018). Adopting additive manufacturing in SMEs: Exploring the challenges and solutions. *Journal of Manufacturing Technology Management*, *29*(6), 937–957. https://doi.org/10.1108/JMTM-02-2018-0030

Matthiae, M., & Richter, J. (2018). *Industry 4.0-induced change factors and the role of organizational agility* (Germany).

Mittal, S., Khan, M. A., Purohit, J. K., Menon, K., Romero, D., & Wuest, T. (2020). A smart manufacturing adoption framework for SMEs. *International Journal of Production Research*, *58*(5), 1555–1573. https://doi.org/10.1080/00207543.2019.1661540

Mittal, S., Khan, M. A., Romero, D., & Wuest, T. (2018). A critical review of smart manufacturing & Industry 4.0 maturity models: Implications for small and medium-sized enterprises (SMEs). *Journal of Manufacturing Systems*, *49*, 194–214.

Mubarak, M. F., Tiwari, S., Petraite, M., Mubarik, M., & Raja Mohd Rasi, R. Z. (2021). How Industry 4.0 technologies and open innovation can improve green innovation performance? *Management of Environmental Quality: An International Journal*, *32*(5), 1007–1022. https://doi.org/10.1108/MEQ-11-2020-0266

Müller, J. M., Buliga, O., & Voigt, K.-I. (2018). Fortune favors the prepared: How SMEs approach business model innovations in Industry 4.0. *Technological Forecasting and Social Change*, *132*, 2–17.

Olavarrieta, S., & Ellinger, A. E. (1997). Resource-based theory and strategic logistics research. *International Journal of Physical Distribution & Logistics Management*, *27*(9/10), 559–587. https://doi.org/10.1108/09600039710188594

Pacchini, A. P. T., Lucato, W. C., Facchini, F., & Mummolo, G. (2019). The degree of readiness for the implementation of Industry 4.0. *Computers in Industry*, *113*, 103125.

Parhi, S., Joshi, K., & Akarte, M. (2021). Smart manufacturing: A framework for managing performance. *International Journal of Computer Integrated Manufacturing*, *34*(3), 227–256. https://doi.org/10.1080/0951192X.2020.1858506

Paulk, M. C., Curtis, B., Chrissis, M. B., & Weber, C. V. (1993). Capability maturity model, version 1.1. *IEEE Software*, *10*(4), 18–27.

Pech, M., & Vrchota, J. (2020). Classification of small-and medium-sized enterprises based on the level of industry 4.0 implementation. *Applied Sciences*, *10*(15), 5150.

Peillon, S., & Dubruc, N. (2019). Barriers to digital servitization in French manufacturing SMEs. *Procedia Cirp*, *83*, 146–150.

Pöppelbuß, J., & Röglinger, M. (2011). *What makes a useful maturity model? A framework of general design principles for maturity models and its demonstration in business process management*.

Rahimli, A. (2012). Knowledge Management and Competitive Advantage. *Information and Knowledge Management*, 37–43.

Rajan, C. A., & Baral, R. (2015). Adoption of ERP system: An empirical study of factors influencing the usage of ERP and its impact on end user. *IIMB Management Review*, *27*(2), 105–117. https://doi.org/10.1016/j.iimb.2015.04.008

Rajput, S., & Singh, S. P. (2018). Identifying Industry 4.0 IoT enablers by integrated PCA-ISM-DEMATEL approach. *Management Decision*.

Rauch, E., Unterhofer, M., Rojas, R. A., Gualtieri, L., Woschank, M., & Matt, D. T. (2020). A maturity level-based assessment tool to enhance the implementation of industry 4.0 in small and medium-sized enterprises. *Sustainability*, *12*(9), 3559.

Rojko, A. (2017). Industry 4.0 concept: Background and overview. *International Journal of Interactive Mobile Technologies*, *11*(5).

Sari, R. P., & Santoso, D. T. (2020). Readiness Factor Identification on Kabupaten Karawang SMEs towards Industry 4.0 Era. *Jurnal Teknik Industri*, *22*(1), 65–74.

Saunders, M., Lewis, P., & Thornhill, A. (2016). Research methods for business students (Seventh). *Nueva York: Pearson Education*.

Schumacher, A., Erol, S., & Sihn, W. (2016a). A maturity model for assessing Industry 4.0 readiness and maturity of manufacturing enterprises. *Procedia Cirp*, *52*, 161–166.

Schumacher, A., Erol, S., & Sihn, W. (2016b). A maturity model for assessing Industry 4.0 readiness and maturity of manufacturing enterprises. *Procedia Cirp*, *52*, 161–166.

Sousa, R., & Voss, C. A. (2008). Contingency research in operations management practices. *Journal of Operations Management*, *26*(6), 697–713.

Sun, J., Sarfraz, M., Turi, J. A., & Ivascu, L. (2022). Organizational Agility and Sustainable Manufacturing Practices in the Context of Emerging Economy: A Mediated Moderation Model. *Processes*, *10*(12), Article 12. https://doi.org/10.3390/pr10122567

Sunigovets, O. (2019). Enterprise competitiveness in the digital economy. *SHS Web of Conferences*, *67*, 04012.

Swierczek, A. (2022). The effects of industry 4.0 technologies on relational performance: The mediating role of supply chain emergence in the transitive logistics service triads. *Supply Chain Management: An International Journal*, *28*(2), 363–384. https://doi.org/10.1108/SCM-07-2021-0347

Szász, L., Demeter, K., Racz, B.-G., & Losonci, D. (2021). Industry 4.0: A review and analysis of contingency and performance effects. *Journal of Manufacturing Technology Management*, *32*(3), 667–694.

Tao, F., Qi, Q., Liu, A., & Kusiak, A. (2018). Data-driven smart manufacturing. *Journal of Manufacturing Systems*, *48*, 157–169. https://doi.org/10.1016/j.jmsy.2018.01.006

Teo, T. S. (2007). Organizational characteristics, modes of internet adoption and their impact: A Singapore perspective. *Journal of Global Information Management (JGIM)*, *15*(2), 91–117.

Themistocleous, M., Irani, Z., Kuljis, J., & Love, P. E. (2004). Extending the information system lifecycle through enterprise application integration: A case study experience. *37th Annual Hawaii International Conference on System Sciences, 2004. Proceedings of The*, 8-pp.

Tortorella, G. L., Giglio, R., & van Dun, D. H. (2019). Industry 4.0 adoption as a moderator of the impact of lean production practices on operational performance improvement. *International Journal of Operations & Production Management*, *39*(6/7/8), 860–886. https://doi.org/10.1108/IJOPM-01-2019-0005

Tortorella, G. L., Vergara, A. M. C., Garza-Reyes, J. A., & Sawhney, R. (2020). Organizational learning paths based upon industry 4.0 adoption: An empirical study with Brazilian manufacturers. *International Journal of Production Economics*, *219*, 284–294.

Trstenjak, M., Lisjak, D., Opetuk, T., & Pavković, D. (2019). Application of multi criteria decision making methods for readiness factor calculation. *IEEE EUROCON 2019-18th International Conference on Smart Technologies*, 1–6.

Vaidya, S., Ambad, P., & Bhosle, S. (2018). Industry 4.0–a glimpse. *Procedia Manufacturing*, *20*, 233–238.

Veile, J. W., Kiel, D., Müller, J. M., & Voigt, K.-I. (2020). Lessons learned from Industry 4.0 implementation in the German manufacturing industry. *Journal of Manufacturing Technology Management*, *31*(5), 977–997.

Wang, M., Asian, S., Wood, L. C., & Wang, B. (2020). Logistics innovation capability and its impacts on the supply chain risks in the Industry 4.0 era. *Modern Supply Chain Research and Applications*, *2*(2), 83–98. https://doi.org/10.1108/MSCRA-07-2019-0015

Wankhede, V. A., & Vinodh, S. (2023). Assessment of Industry 4.0 performance using scoring approach: A case study. *The TQM Journal*, *ahead-of-print*(ahead-of-print). https://doi.org/10.1108/TQM-08-2022-0262

Widayani, A., Astuti, E. S., & Saifi, M. (2020). Competence and readiness of small and medium industries against of industrial revolution 4.0. *IOP Conference Series: Earth and Environmental Science*, *485*(1), 012114.

Wieder, B., Booth, P., Matolcsy, Z. P., & Ossimitz, M. (2006). The impact of ERP systems on firm and business process performance. *Journal of Enterprise Information Management*, *19*(1), 13–29. https://doi.org/10.1108/17410390610636850

Won, J. Y., & Park, M. J. (2020). Smart factory adoption in small and medium-sized enterprises: Empirical evidence of manufacturing industry in Korea. *Technological Forecasting and Social Change*, *157*, 120117.

Xu, L. D., Xu, E. L., & Li, L. (2018). Industry 4.0: State of the art and future trends. *International Journal of Production Research*, *56*(8), 2941–2962. https://doi.org/10.1080/00207543.2018.1444806

Yang, S., & Kang, H.-H. (2008). Is synergy always good? Clarifying the effect of innovation capital and customer capital on firm performance in two contexts. *Technovation*, *28*(10), 667–678.

Yüksel, H. (2020a). An empirical evaluation of industry 4.0 applications of companies in Turkey: The case of a developing country. *Technology in Society*, *63*, 101364.

Yüksel, H. (2020b). An empirical evaluation of industry 4.0 applications of companies in Turkey: The case of a developing country. *Technology in Society*, *63*, 101364.

Yurtyapan, M. S., & Aydemir, E. (2021). ERP software selection using intuitionistic fuzzy and interval grey number-based MACBETH method. *Grey Systems: Theory and Application*, *12*(1), 78–100. https://doi.org/10.1108/GS-01-2021-0002

Zhang, M., & Lv, Z. (2021). The Influencing Factors of Financial Support Efficiency of New Generation High-Tech Industry in China: Evidence from Listed Companies. *Theoretical Economics Letters*, *11*(4), Article 4. https://doi.org/10.4236/tel.2021.114050

Zheng, L., Ulrich, K., & Sendra-García, J. (2021). Qualitative comparative analysis: Configurational paths to innovation performance. *Journal of Business Research*, *128*, 83–93.