

Recent Advances in Smart Manufacturing: A Case Study of Small, Medium, and Micro Enterprises (SMME)

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ABSTRACT: The digital revolution is the future pathway to experiencing business evolution. It will be difficult for any organization to remain in business without deploying fourth industry revolution (4IR) techniques. This review guides prospective business owners on the need to embrace Smart Manufacturing (SM) timely and appropriate to enhance their business performance indicators. Many manufacturing companies are facing challenges in adopting SM tools in their organization due to a lack of essential resources despite the benefits associated with SM. Therefore, this study systematically reviewed the criteria evaluation techniques in implementing digital factories. This work has analysed small, medium, and micro enterprises (SMME), with the view to enumerate the appropriate criteria to determine the level of digital technology tools adoption framework. It also highlights how to compensate for the inadequate technical and financial resources in SM. The guidelines for SM implementation adoption in SMME is a research gap that was missing in previous studies. SM benefits, challenges, applications, significance, impact, and future perspectives, are discussed. Evaluation Criteria for SM Adoption practices were also expounded. The framework used in this study will help SMME owners to adopt SM.

KEYWORDS: Automation, Digitalization, Smart Manufacturing, Fourth Industrial Revolution, Artificial intelligence

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I. INTRODUCTION

Population growth and urbanization have led to an increased demand for products. The advent of the industrial revolution has also made the migration from conventional manufacturing systems to a technology-driven manufacturing system inevitable. Diverse consumer preferences and the need to increase production, ensure sustainable energy utilization, and predict and identify errors in manufacturing gave birth to the deployment of innovative smart technologies in SMMEs. Since the advent of smart manufacturing, new products, and the marketplace have progressively been witnessed. SM uses computer-aided manufacturing, flexible design, digital information technology, and flexible technical workforce training (Bi *et al.*, 2021). Smart manufacturing is a broad concept; It is a combination of artificial intelligence, big data, the Industrial Internet of Things, smart data, cyber security, condition monitoring, robotics, automation, visualization, and cloud computing to achieve optimal technological solutions that meet customer satisfaction and needs when implemented in a manufacturing ecosystem (Figure 1) (Qu *et al.*, 2019, Shukla and Shankar, 2021, Zeid *et al.*, 2019). Smart manufacturing is governed by data, and understanding data trends makes it possible to interpret the scenario and how best to manipulate it to optimize processes (Wunderle *et al.*, 2018). SM concept enables skilled workers to automatically collect

and analyze data to make better-informed decisions and optimize production (Leng *et al.*, 2021). Various researchers have reported the continuous accelerated growth of SM in various aspects of industries (Shahbazi and Byun, 2021a, Del Giudice *et al.*, 2021, Parhi *et al.*, 2021) such as automotive, aerospace, electronics, plastics, assembly plants, etc. since it offers a better solution to critical challenges confronted in such industries (Shukla and Shankar, 2021, Wunderle *et al.*, 2018). Although there are recordable setbacks for the adoption of SM as a viable option to provide satisfaction to customers' needs. Current research has shown that SM will provide a permanent solution to the challenges that erupted as a result of a shortage of skilled workers in the industries Cioffi *et al.*, 2020, Ferrer *et al.*, (2018). The trend of SM adoption records globally from 2005 to date is shown in (Figure 2) (Volk *et al.*, 2022). The progressive increase in Figure 2 is an assurance that future SMME success lies in business digitalization. SM provides a greater advantage for manufacturers that skillfully implement it (Thoben *et al.*, 2017, Ferrer *et al.*, 2018, Davis *et al.*, 2015, Kinkel *et al.*, 2022, Cagliano *et al.*, 2021). There are notable features of SM such as context awareness, modularity, heterogeneity, interoperability, and compositionality that need to be well managed to function without human involvement (Kotsiopoulos *et al.*, 2021, Qiao *et al.*, 2021, Chandra Shekhar Rao *et al.*, 2021).

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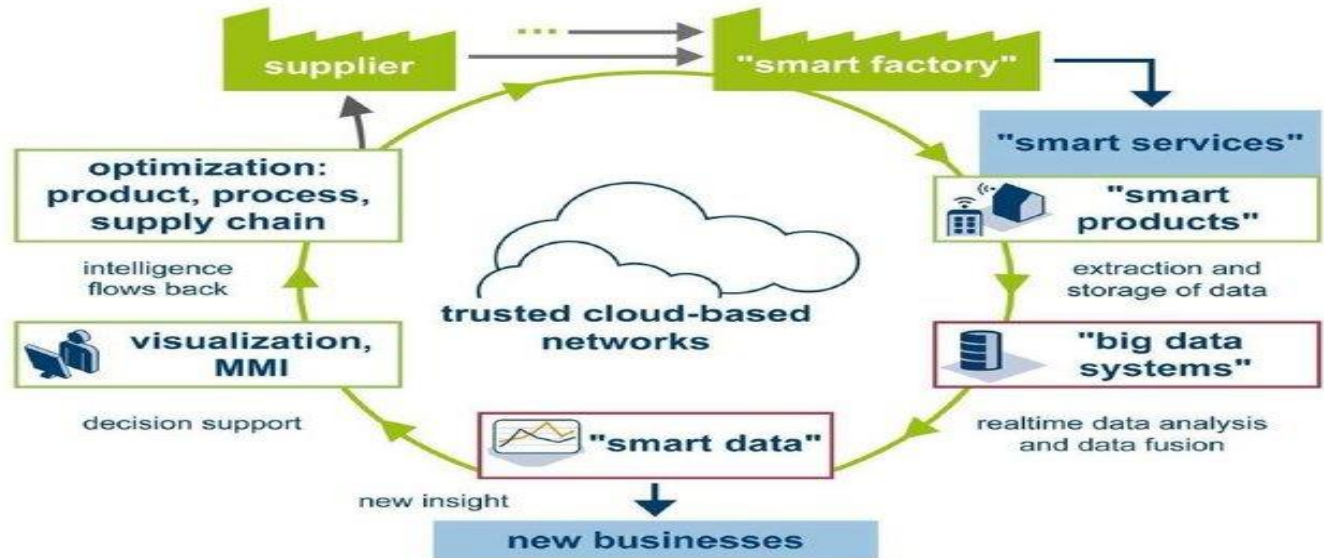


Figure 1: Smart Manufacturing Systems (Qu et al., 2019)

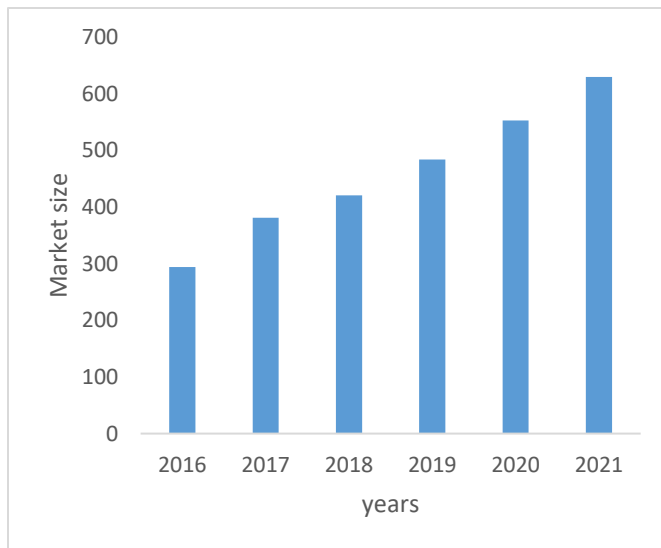


Figure 2: Global Smart industry trend from 2016 to 2021 (Volk et al., 2022)

performance as related to quality, quantity, time, cost, flexibility, and health and safety in the workplace (Sharifi et al., 2021, Nazir et al., 2021). The digitalization of product design, supply chain management, production processes, distribution of products, monitoring of sales performance, and customer satisfaction in the future way of doing business for any manufacturing firm or SMME who wishes to remain in the global competitive market (Mondejar et al., 2021, Viswanathan and Telukdarie, 2021). Previous studies have explained the need, and benefits of SM in the global market (Guo and Martinez-Garcia, 2021, Shen et al., 2021, Bustinza et al., 2021). SM global market increase is related to the need to automate business processes to achieve efficiency and quality (Figure 3) (Bustinza et al., 2021), the smart technology growth by different industries: automotive, aerospace, chemical and materials, healthcare, industrial equipment, electronics, food and agriculture, oil and gas, and other from

2014 and forecast to 2025 is an indication that most conventional factory shall soon adopt SM (Figure 4) (Moiceanu and Paraschiv, 2022, Qian et al., 2021).

However, the global adoption index for SM by the best thirteen countries by their practices and future expansion plan as related to smart factory growth from 2019 to 2024 is shown in Figure 5 (Mittal et al., 2020). Prerequisites for the adoption of SM can be classified into three main criteria: technological, financial, and human resources capabilities for the purpose of ascertaining the level of readiness (Kinkel et al., 2022, Marinas et al., 2021). Although there are many studies on SM adoption, growth, implementation, applications, benefits, barriers, market share, trends, etc. But there is a deficit of literature on guidelines for SM implementation strategy. This literature review explains the guidelines for the successful implementation of SM techniques in SMMEs.

II. SM BENEFITS

SM uses Artificial Intelligence (AI), sensors, the Internet of Things (IoT), Big data, quality control, smart planning, and supply chain, to enhance flexibility, productivity, and efficiency (Cagliano et al., 2021, Moran, 2022). SM promotes communication, competence, Real-time reporting, automation, aids in quick solutions to problems, and fast decision-making (Sivaji et al., 2020, Wang et al., 2018). It helps to monitor every manufacturing process from the raw materials stage to final product delivery and market performance. Computer integrated manufacturing system helps to increase the processes' capability and waste reduction (Abubakar et al., 2020, Mehrpouya et al., 2019, Büchi et al., 2020). Again, since data can be generated in real-time; good quality, maintenance prediction, workers' safety, asset utilization, reduce lead time, prediction of machine failure, energy consumption management, zero waste, and elimination of human error is guaranteed in SM (Wang et al., 2018, Moshiri et al., 2020, Haricha et al., 2020). The benefits of smart manufacturing are

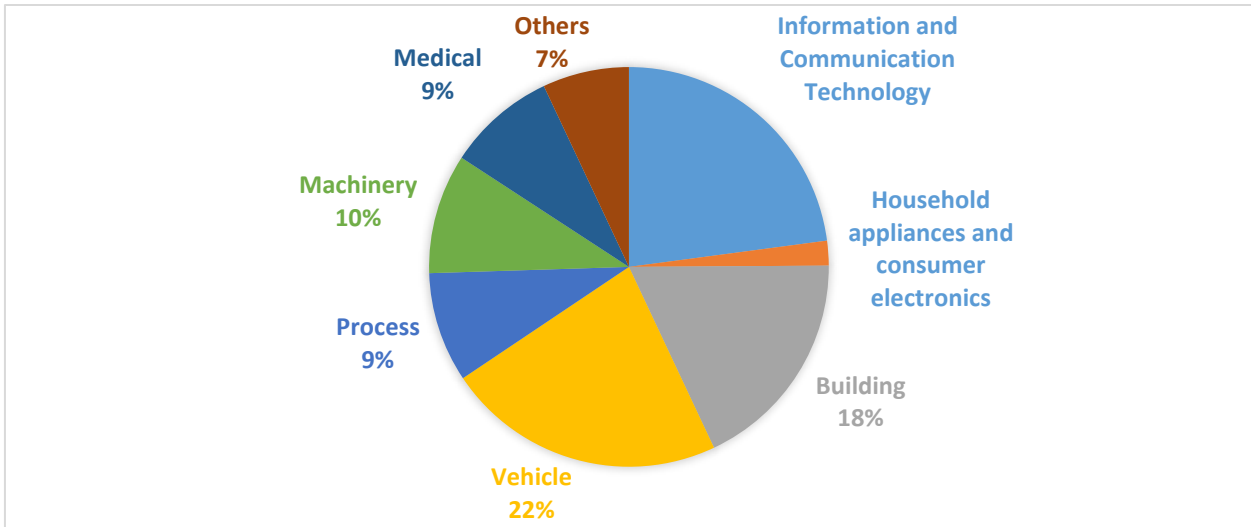


Figure 3. Smart Manufacturing Market Global Industries Analysis, and Forecast 2027 (Bustinza et al., 2021)

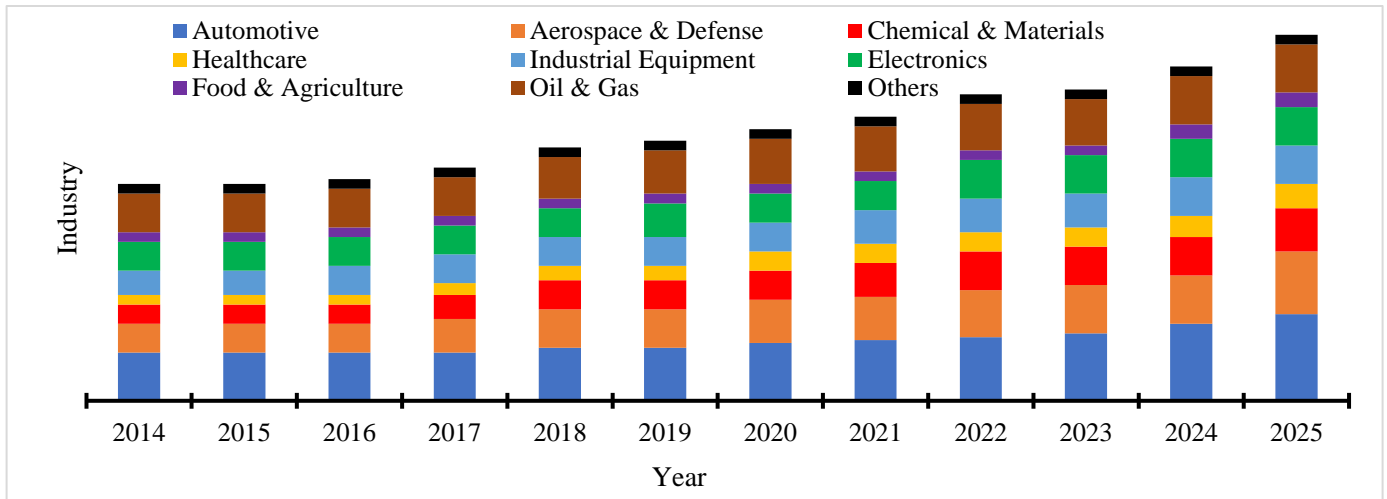


Figure 4. SM adoption trend from 2014 to 2023 and the 2025 forecast (Moiceanu and Paraschiv, 2022, Qian et al., 2021)

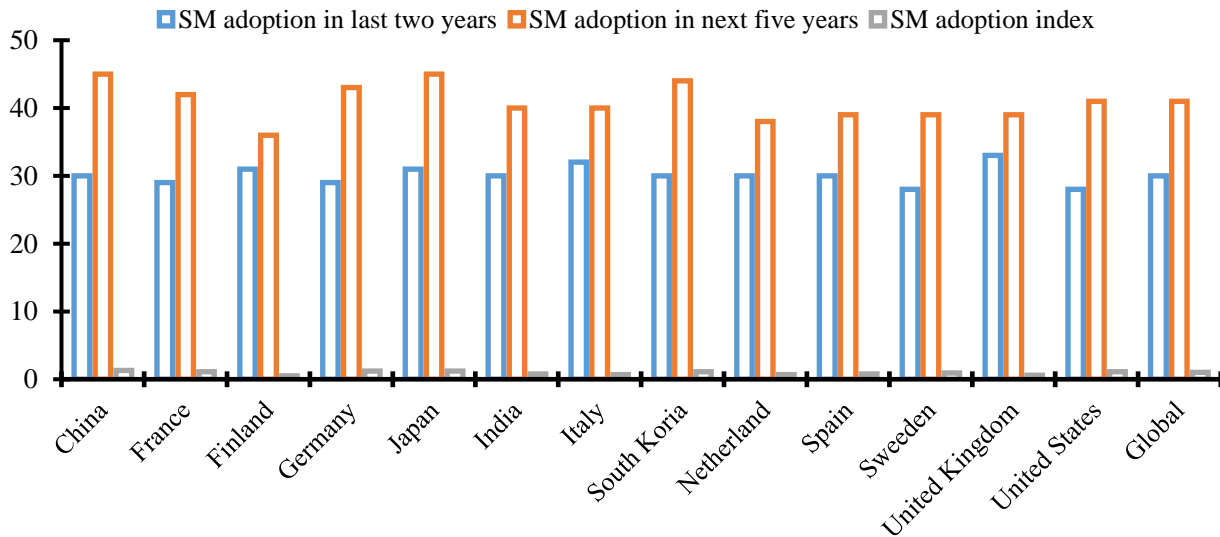


Figure 5: Smart factory growth from 2019 to 2024 (Mittal et al., 2020)

complemented by human skill and innovation. Although SM has many benefits, its overall success depends on human inventiveness, knowledge, and awareness. Other benefits of digital transformation in SMME include low production reduction cycle time through material flow and assembly line processes; monitoring of various cutting tools parameters; Testing of products and equipment to detect the quality of products and equipment failure; Traceability of products from manufacture to the supply chain and delivery; Manage machinery utilization techniques and reduce downtime with better maintenance predictability tools; Accurate planning for consumer demand and responsiveness to meet the change in customers' demand; Increased innovation and collaboration opportunities; Optimization of materials, equipment, work stations; in real-time, remote monitoring of facilities, safer working environments for employees through the use of robotics. Table 1 depicts the functional roles played by the technological tools in the smart-related industries.

robotics, sensors, electrical and electronics as shown (Figure 6) to meet the global market demand and customers' needs.

The giant leap in SM has been achieved through the evolution of smart technological tools such as big data, the use of sensors, cloud computation, IoT, Robotic/automation, AI, Augmented Reality (AR), and additive manufacturing (Leng *et al.*, 2021, Shahbazi and Byun, 2021a). Many SMMEs are yet to embrace the provisions available in the SM due to technical requirements for its implementation. However, it will be difficult for any company to enjoy future business plans and strategies without engaging in the 4IR technologies (Elahi and Tokaldany, 2021). The interdependence of smart technological tools and the architectural ecosystem of a smart factory is shown in (Figure 7). Global smart factory size and future projection are depicted in (Figures 7 and 8). There is an increase in the adoption of SM globally.

Table 1. Role of SM in 4IR

S/N	Provisions	Ref.
1	Increased Knowledge Sharing and Collaboration among workers and other firms	(Lepore <i>et al.</i> , 2022, Baroroh <i>et al.</i> , 2021)
2	Reduced production cycle and lead time to meet customers' need	(Dey <i>et al.</i> , 2021, Leng <i>et al.</i> , 2021)
3	Reduced raw material, work-in-progress, and finished products inventories	(Ghouat <i>et al.</i> , 2021, Tripathi <i>et al.</i> , 2021)
4	Reduced the number of workforces and hence minimised labour costs	(Pfeifer, 2021, Jamwal <i>et al.</i> , 2021, Zhou <i>et al.</i> , 2022)
5	Flexibility in production and work schedules	(Serrano-Ruiz <i>et al.</i> , 2021, Serrano-Ruiz <i>et al.</i> , 2022)
6	SM improves machine availability and reduces machine downtime	(Patel <i>et al.</i> , 2018)
7	It promotes high machine utilization hours	(Ku <i>et al.</i> , 2020, Lyu <i>et al.</i> , 2020)
8	It helps in radical Innovation strategy	(Larsen and Lassen, 2020, García-Muñia <i>et al.</i> , 2020)
9	It promotes customer needs and satisfaction	(Wang <i>et al.</i> , 2021d, Dey <i>et al.</i> , 2021, Parhi <i>et al.</i> , 2021)
10	Return on Investment is faster and more predictable	(Kamat <i>et al.</i> , 2021, Haricha <i>et al.</i> , 2021, Rizvi <i>et al.</i> , 2021)
12	Response to market changes is timely	(Del Giudice <i>et al.</i> , 2021, Qi <i>et al.</i> , 2021, Patalas-Maliszewska and Topczak, 2021)
14	The number of tools, machine spare parts, and machinery required in smart industries is usually smaller compared to conventional manufacturing factory	(Zheng <i>et al.</i> , 2018)
15	It is easy to expand the production line or expand the facilities to accommodate more machines.	(Dobrilovic <i>et al.</i> , 2021, Ke <i>et al.</i> , 2022)
17	Improve efficiency, enhance product quality and promote at workplace	(Meng <i>et al.</i> , 2018, Qi and Tao, 2018, Shahbazi and Byun, 2021a, Uysal and Mergen, 2021, Tripathi <i>et al.</i> , 2021)
18	Increased business Profitability margin	(Li <i>et al.</i> , 2021a, Yonghui and JIANG, 2021)
19	Efficient energy management is possible	(Kumar <i>et al.</i> , 2021, Li <i>et al.</i> , 2021a, Wang and Luo, 2021)

III. SM APPLICATION AREAS

There is sufficient literature on SM applications from recent studies, this is due to the numerous benefits associated with 4IR. These include the ease of doing business, high efficiency, high productivity, product innovation, business competitiveness, low production cost, improved processes, good quality, waste reduction, environmentally friendly production system, quality inspection, quality assurance, material handling, reduced lead time, customer satisfaction and quick return on investment (Baroroh *et al.*, 2021, Kotsiopoulos *et al.*, 2021, Li *et al.*, 2021c). The smart factory market is increasing globally. There is an increase in global SM applications majorly in the field devices such as (PLCs, sensors, actuators, and HMIs), automotive, aerospace,

IV. GUIDELINES FOR IMPLEMENTATION OF SM TECHNIQUES IN SMME

Digitalization of SMME benefits has been justified by a gamut of literature, however, adopting and implementing digital technology in SMME comes with its challenges (Jwo *et al.*, 2021). However, these challenges can be resolved by using the following guidelines:

A. Organization goal and objectives

The development plan must be clearly stated to determine the assessment criteria for the adoption of smart technology requirements that will be suitable (Badhotiya *et al.*, 2021).

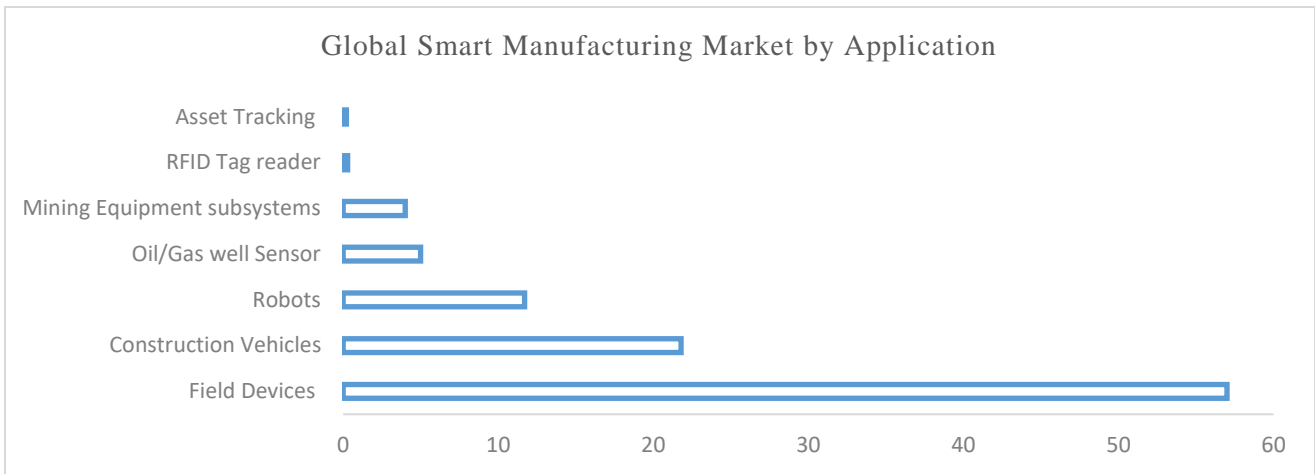


Figure 6: Smart Manufacturing Market by Application (Bustinza et al., 2021)

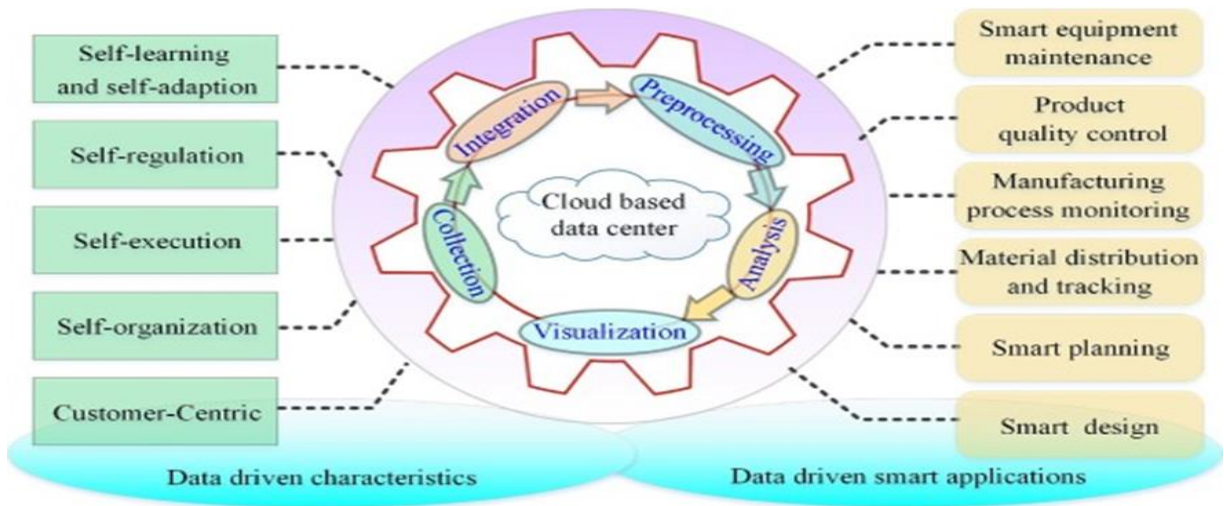


Figure 7: Data-driven smart manufacturing (Bustinza et al., 2021)

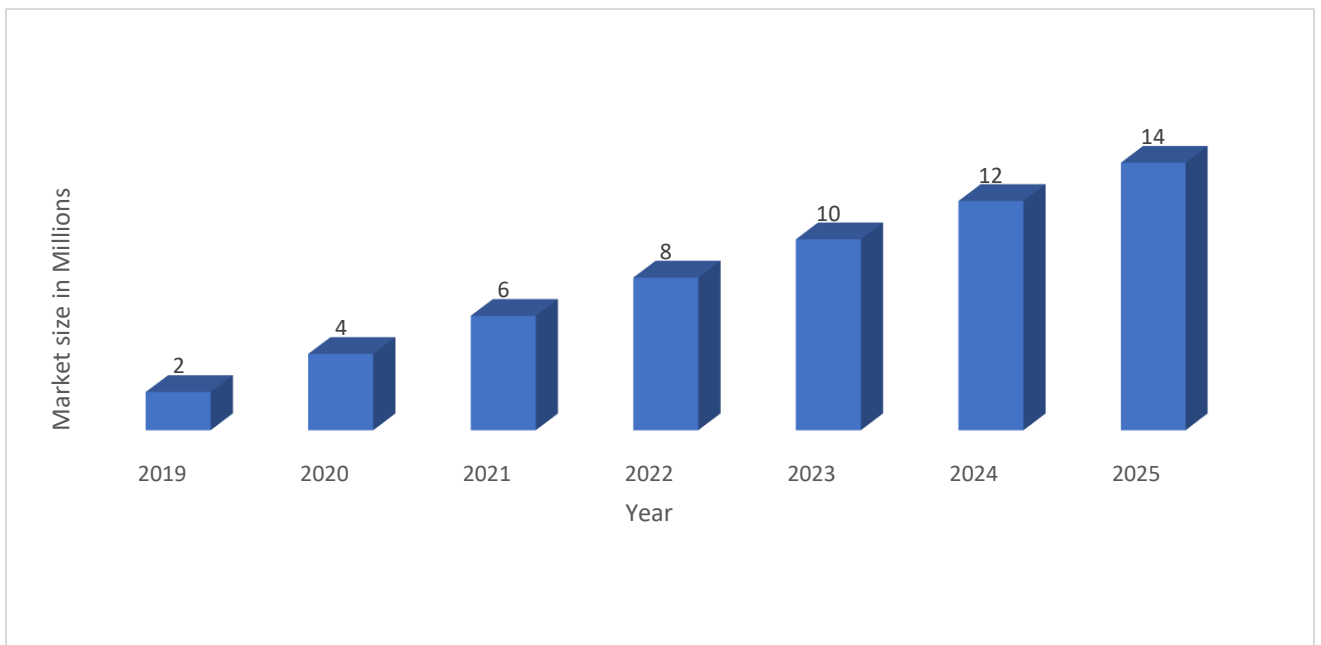


Figure 8: Global smart factory market size report (Bustinza et al., 2021)

B. Capacity

The size of the SMME and the expansion provision envisaged by the management need to be considered (Edwards, 2021). There is a need for the management to study the business indicator before embarking on digital business technology to avoid over-investment. If the proper business assessment is done, it will help the management to understand the level of smart technology to be adopted within the context of organizational vision (Qiao *et al.*, 2021, Del Giudice *et al.*, 2021).

C. Technical deficit

Management should review the business process critically to identify the area of need to deploy smart technological tools (Chauhan and Singh, 2021). This will go a long way to justify the cost of adopting SM and compensate for the return on investment.

D. Reliability of the existing system

There is a need to thoroughly review the traditional method of doing business and then identify areas of the critical need to seek digital intervention (Friederich *et al.*, 2021). This will help to reduce the overall cost of SM implementation. The size of the business will help to make a critical analysis of the area of digital technology tools that are required at each business stage to remain competitive in the market. This guarantees the right size of digital business investment cost.

E. Analysis of Predictive maintenance

Helps to eradicate unplanned downtime by predicting equipment failure based on usage and performance data (Chen *et al.*, 2021). These promote business continuity and machine production output.

F. Scope

The technical and technological limits of adopting a different level of factory digital tools should be studied and evaluated by the top management team of experts to leverage the optimum benefits that can be accessible by implementing SM in terms of competitiveness, sustainability, market share and customer needs (Ante, 2021).

G. Process capability

The relevance of the SM on the overall quality of the product should be predetermined. Again, the rate by which the processing time would be reduced should be analyzed by the business stakeholders to establish the magnitude of digital technological tools to be purchased (Tucker, 2021, Abd Rahman *et al.*, 2021). This will justify the cost/benefit analysis of the business owners.

H. Finance

The total cost of adopting a specific level of SM to be implemented in a factory should be decided (Dey *et al.*, 2021, Çınar *et al.*, 2021). How to source for the fund should be sorted out with robust payback planning (Jang *et al.*, 2022). This will help the management to decide the level of adoption suitable at a time, this will help the management and business owners to enjoy the flexibility associated with the SM.

I. Efficiency

The level of efficiency envisaged by the management/business owners should be predetermined before implementing SM by using simulations and other predictive tools before heavy investment in smart business technology (Bermeo-Ayerbe *et al.*, 2022).

J. Time

Implementation of digital technology in the business should be factored out, and strategy on how to maintain make share during the implementation should be determined (Zhang *et al.*, 2021). And most importantly, the management needs to decide the best time to adopt the SM. Failure to adopt SM timely may lead to business extinction.

K. Training

The adequate training needs for the staff who will operate the SM effectively should be decided ahead of its implementation (Wang *et al.*, 2021c). This will guide management and business owners' judgment and the financial implications of training.

L. Acceptance

The readiness of the workers and unions to accept the implementation of SM should be determined and when there is low acceptance, the management should sensitize the workers on the need to adopt digital technologies (Schein and Rauschnabel, 2021). The fear of workers about SM is loss of jobs through redundancy of staff. Management should deploy goodwill and readiness to address all the bottlenecks.

M. Quality

SM applications can be deployed to monitor product quality and process in real-time to reduce process variability, and eliminate errors in the process to reduce rework costs and scraps (Barari *et al.*, 2021). The significance of quality monitoring to the SMME should be ascertained by the stakeholders.

N. Sustainability

Can the management meet up with the financial obligation associated with the implementation of SM? There is a regular need to update better technology and newer visions as the case may be. SM systems integration with open interoperable APIs allows manufacturers to respond promptly to changes in equipment, product configuration, process, labels, and packaging. A smart factory can easily be reconfigured to scale down or scale up production quantity, allow the introduction of new products, create one-off production runs, and create flexible manufacturing opportunities (Kumar *et al.*, 2021).

V. SMART MANUFACTURING TECHNOLOGIES

The technological evolution in various dimensions and space has been harnessed to run smart manufacturing according to research studies. Table 2 shows examples of SM technologies and their functions.

Table 2. Typical Smart Technologies and Their Uses

Technologies	Explanation	Uses	Ref.
Artificial Intelligence (AI)	AI is the use of the computer to recognize data patterns recognition and data process faster on the factory floor.	Artificial intelligence is used in logistics and robotics. AI is a useful technological tool in supply chain management, autonomous vehicles factory automation, and Information Technology (IT) operations. Other areas of AI applications are; design and manufacturing, warehouse management, process automation, predictive maintenance, AI-based product development, AI-based connected factory, AI-based visual inspections, and quality control. AI is also useful in analyzing purchasing, price variance, and cybersecurity.	(Nica <i>et al.</i> , 2021, Kotsiopoulos <i>et al.</i> , 2021, Wang <i>et al.</i> , 2021b, Lázárouiu <i>et al.</i> , 2021)
Augmented Reality/Virtual Reality	The art of using computers, control systems, and information technology to coordinate processes and machinery.	It is used for Training, disseminating digital work instructions, product variation adaptation, Quality assurance, Ergonomics, manual data process, and analysis.	(Warke <i>et al.</i> , 2021, Sharma <i>et al.</i> , 2021, Blaga <i>et al.</i> , 2021)
Automation/Robotics	the use of computers, control systems, and information technology to coordinate processes and machinery, replacing manual labour and improving efficiency, speed, quality, and performance	It is used to replace manual labour. It improves efficiency, speed, and quality and performs Material handling. The other purpose of Automation/Robotics are Material dispensing, Material removal, Palletization and de-palletizing, and Welding Assembly.	(Javaid <i>et al.</i> , 2021) (Nicora <i>et al.</i> , 2021, Fazlollahabbar, 2021)
Additive Manufacturing	Additive manufacturing is the process of fabricating an object by the addition method (building one layer upon another until the desired product is achieved) instead of the subtractive method.	Rapid prototyping uses digitized technologies for converting 3D models into physical components and is therefore compatible with the full digitization of smart factories. Additive manufacturing is now widely used in the area of product design, manufacture, and service areas of smart factories	(Majeed <i>et al.</i> , 2021, Ashima <i>et al.</i> , 2021, Zenisek <i>et al.</i> , 2021)
Big data	Big Data is continuously generated data produced by machines, sensors, controllers, load cells, flow metre, etc. to optimize and predict activities in SM	It is for Faster Integration of Automation. Predict Machine Failure and help with maintenance planning, reduce machine downtime, promote product quality and reduce operational costs. It Improves research, promote customer service and increased business competitiveness	(Wang and Luo, 2021, Qiao <i>et al.</i> , 2021, My, 2021)
Cloud Computing	Cloud computing is the delivery of different services by using the Internet. Some of these services are; data storage, servers, databases, networking, and software. Cloud-based storage makes it possible to save files to a remote database and retrieve them when they are needed.	It offers faster innovation, flexible resources, and economies of scale. It Promotes competitiveness. and enhances information sharing. It reduces investment cost	(Xia <i>et al.</i> , 2021, Wang <i>et al.</i> , 2021a, My, 2021)
CNC Machining	CNC machining is a manufacturing process that involves the utilization of computerized controls to operate and manipulate machines and cutting tools to shape given materials	It helps to Reduce operational costs, Increased productivity, enhance the consistent quantity, It promotes high flexibility and product repeatability. CNC increases productive hours, and high accuracy. reduced lead time and use of automatic material handling	(Liu <i>et al.</i> , 2021, Li <i>et al.</i> , 2021b)
Design for Manufacturing	Design for manufacturing is a design methodology that enables prefabrication through a set of design options to promote the optimization and rapid prototypes	It helps to reduce manufacturing costs, enhances manufacturers to identify and prevent mistakes, and reduces the complexity of manufacturing. It lowers assembly costs and saves time and labour.	(Phuyal <i>et al.</i> , 2020, Qi <i>et al.</i> , 2018, Sharp <i>et al.</i> , 2018)

VI. SIGNIFICANCE OF SMART MANUFACTURING IMPLEMENTATION

Implementing a digitalized manufacturing system has numerous significance which can be classified according to the reduction in operating expenses they offered.

A. Optimization of resources

Digitalization of manufacturing factories enables the business owner to effectively determine the number of staff

that will be required to manage the factory with a well-defined organogram and job description of every staff. This will help to eliminate waste in terms of staff training, and over staff and reduce the welfare appropriated to salary and wages (Patalas-Maliszewska and Topczak, 2021, Lassen and Waehrens, 2021). Digitalization also helps to improve manufacturing forecasts, production schedules, raw materials inventory management, and overall factory resources management to reduce waste and improve productivity.

B. Predictive maintenance

Smart Manufacturing makes it possible with the application of sensors and transducers to detect, and identify breakages, wear and tear, and possible occurrence at any point of the production in the machine line. By so doing, you can apply predictive maintenance with the aid of Artificial Intelligence and Machine Learning to perfectly predict machine failures and therefore do adequate maintenance planning to resolve them. This will help to save time and cost.

C. Reduction of manpower processes

The digitalized working environment enables proper work-study and engagement of the right size of staff. This helps the factory to retain only skilled workers and engage casual staff where necessary to reduce waste in terms of human resources. By accessing data in real-time through IoT, we will free part of the team from certain tasks to focus on other much more important ones.

D. Increased productivity

Achieving efficiency is a key objective in any business. And, as mentioned in the previous point, spending time on irrelevant tasks is not profitable. Automating these activities will help the team to be much more productive and motivated, as they will not be managing repetitive and tedious tasks. In addition, the reduction of unplanned downtime due to equipment failure will be drastically reduced, maintaining stable and uninterrupted production.

VII. SM IMPACT IN SMME

The introduction of smart manufacturing to the manufacturing sector in recent years has indeed been responsible for the giant leap being recorded (Dey *et al.*, 2021). The future of manufacturing depends on the adoption of SM (Del Giudice *et al.*, 2021). The advent of technological development and data deployment in manufacturing sectors helps to improve productivity, efficiency, process capability, and business sustainability (Andronie *et al.*, 2021, Yalcinkaya *et al.*, 2021). Any manufacturer who fails to adopt smart manufacturing may not be able to compete favourably in the global market and will likely go to extinction over time (Yalcinkaya *et al.*, 2021, Didaskalou *et al.*, 2021). SM has made business technological innovation possible through the art of research and development, monitoring processes to good quality products to market, and customer satisfaction (Cohen and Macek, 2021). Technology has made it possible to determine the right quantity of goods to be produced for certain people at a time to eliminate the inventory of raw materials and finished goods. It also helps to manage the right number of staff required at a time to produce the specified quantity of goods that meet customer needs (Rinaldi *et al.*, 2021). The future success of any manufacturing firm depends on its readiness to adopt smart factory technology (Kumar *et al.*, 2021).

VIII. CHALLENGES OF SM

Despite the huge benefits derived from SM, its potential has not been harnessed fully because of challenges associated with the adoption strategy (Phuyal *et al.*, 2020, Mittal *et al.*, 2020,

Ghobakhloo, 2020). Some of the identified setbacks in adopting SM include the following: Integration of existing machines to a smart environment is difficult; they often require replacement of machinery which attracts high cost (Oh and Jeong, 2019). It is not always easy for business owners to spend money to replace functional machinery. Financial obligations to fund the IoT, and the wireless connection among other smart compliance facilities have discouraged many SMMEs from adopting SM (Saqlain *et al.*, 2019). Highly skilled workers are needed (Jwo *et al.*, 2021, Pixley *et al.*, 2021) to run and maintain smart factories; this is also a major concern that inhibits SM adoption. The fear that the business strategy can be hacked or halted through cybercrime (Yao *et al.*, 2019) is another concern preventing the adoption and implementation of SM among SMME business owners. Adopting smart factory technology comes with numerous challenges and implications (Di Cataldo *et al.*, 2021, Leng *et al.*, 2021). There is a need to understand a systematic approach to follow to move from the conventional way of doing business to smart technology. There are no specific documented steps to follow in implementing smart technologies. This makes it difficult sometimes for the intended manufacturing firm who are willing to harness the benefits of SM. Some of the challenges in adopting smart technology include finance, internet connectivity, cyber security, lack of skilled workers, and many others (Mourtzis *et al.*, 2021, Parhi *et al.*, 2021, Shahbazi and Byun, 2021b). However, each manufacturing company willing to adopt smart technology needs to do an internal analysis of their existing facilities and the level of adoption they can afford in terms of financial capability. Adopting smart technology by existing business owners is flexible (Sajjad *et al.*, 2021). It can be done gradually stage by stage; this allows the business owners to progressively enjoy the benefits of smart technology until there is full adoption of smart technology. Again, SM tends to improve the overall performance of businesses and manufacturing firms (Parhi *et al.*, 2021). SM makes business operations sustainable as a result of data management in real-time that enables proper coordination of information, raw materials, machinery, and men (Kumar *et al.*, 2021, Jamwal *et al.*, 2021, Tripathi *et al.*, 2021).

IX. CONCLUSION

This study has succeeded in highlighting the recent advances in SM as related to its adoption, benefits, challenges, and future perspectives. Though there are many studies on SM, this literature review emphasizes the guidelines for SM implementation adoption. The results of this research will enrich the scholar community by providing consolidated information on SM adoption evaluation criteria, and implementation strategy. Despite the innovative achievement that has been recorded in the application of smart technology globally, a lot still needs to be done to enhance further collaboration, information sharing, and synergy among industries to improve and sustain the global economy.

This study will serve as a guide to SMMEs who are willing to adopt digital technology. As a matter of urgency, more applied research is needed on the smart technology revolution to further promote productivity, efficiency, quality, quick return on investment, reduce lead time, reduce operational cost,

and promote industrial development. The findings in this study reveal that despite the numerous benefits associated with the Smart technology, its adoption in South Africa is slow especially in SMMEs because of finance, technical skill, and smart technologies required. Manufacturers, researchers, business owners, industrialists, and policymakers will benefit from this research and use the information herein as a basis for more studies. This review shall help to simplify the step-by-step guidelines to enable SMMEs to adopt smart technology.

AUTHOR CONTRIBUTIONS

Conceptualization, **K.A.Bello, M.G. Kanakana-Katumba, R.W. Maladzi, and C.O. Omoyi**; methodology, **K.A.Bello, M.G. Kanakana-Katumba, R.W. Maladzi, and C.O. Omoyi**; investigation; **K.A.Bello, M.G. Kanakana-Katumba, R.W. Maladzi, and C.O. Omoyi**, writing-original draft preparation, **K.A.Bello**; writing review and editing; **K.A.Bello, M.G. Kanakana-Katumba, R.W. Maladzi, and C.O. Omoyi**, project administration, **K.A.Bello**; All authors have read and agreed to the published version of the manuscript.

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