SMME Readiness for Smart Manufacturing (4IR) Adoption: A Systematic Review

Lucas Gumbi, Hossana Twinomurinzi

SMME Readiness for Smart Manufacturing (4IR) Adoption: A Systematic Review

Lucas Gumbi[1][0000-0002-5483-8349] and Hossana Twinomurinzi[2][0000-0002-9811-3358]

[1] University of South Africa, 28 Pioneer Ave, Florida Park, Roodepoort, South Africa
58563199@mylife.unisa.ac.za
[2] University of South Africa, 28 Pioneer Ave, Florida Park, Roodepoort, South Africa
twinoh@unisa.ac.za

Abstract. Smart manufacturing, Industry 4.0 and Smart Factory are phenomena regarded as a key necessity for Small, Medium and Micro Businesses (SMMEs) worldwide. Even though these 4th Industrial Revolution (4IR) phenomena are generally used interchangeably, this paper sought to identify how SMME readiness for smart manufacturing has been investigated through a systematic review. The systematic review was conducted through the lens of Nooteboom, and Tornatzky and Klein's research on technological innovation in SMMEs based on Rogers' diffusion of innovations theory. The findings reveal that there is little to no research on smart manufacturing in relation to SMMEs in low-income countries particularly the African continent. The results also show that smart manufacturing is still an emergent phenomenon with disparate definitional challenges. These definitional challenges make the adoption of smart manufacturing innovations a challenge in resource-constrained contexts; but similarly present an opportunity for new definitions and theories in such contexts. The little research often treats SMMEs homogenously and as such misses their important heterogeneous (sector or industry specific) nature. Few research studies investigate SMME awareness (adequate knowledge) or make explicit the benefits (relative advantage) of smart manufacturing. Even fewer studies are explicit on the smart manufacturing technologies that are relevant for different SMME sectors. Smart manufacturing is identified as incompatible with SMME characteristics, that is SMMEs lack expertise/skills to comprehend the complexity of smart manufacturing, and also lack financial and human resources to implement smart manufacturing. Given that awareness, relative advantage, complexity and compatibility are critical barriers for SMME smart manufacturing readiness/adoption, there is a critical need for research to focus on these factors in particular for the context of resource constrained low-income country environments.

Keywords: Smart Manufacturing, Industry 4.0, SMMEs, 4th Industrial Revolution, 4IR

1 Introduction

Smart Manufacturing is an emerging 4th Industrial Revolution (4IR) phenomena as a result of the convergence of various Information and Communication Technologies

(ICT) that improve manufacturing factors such as productivity, quality, delivery and flexibility [1–4]. Smart manufacturing relates to enabling industries and their manufacturing ecosystems to connect and adopt novel efficiency gains along their value and supply chains [5]. Smart Manufacturing as a new technological innovation is also seen as a key driver of improved manufacturing operations [6, 7] and a catalyst of manufacturing intelligence [8].

However, despite all the mentioned benefits, SMMEs are not ready for the adoption and implementation of smart manufacturing as compared to larger firms [9–12]. Jun et al. [9] attribute this to the SMME environment, their underdeveloped capabilities, and practical limitations such as cost and personnel. Muller and Voigt [10] suggest that the challenge is with SMME business model constraints, while Luff [12] and Safar et al. [11] highlight the issue of lack of resources as the primary constraint.

There have been other systematic reviews [5, 13–18] to understand the factors inhibiting smart manufacturing adoption and implementation by SMMEs. Those reviews focused on different dimensions [5, 13–16] and contextual perspectives [17, 18]. For example, Mittal et al. [5, 13, 14] focused specifically on maturity models, while Hamdi [16] and Moeuf et al. [15] focused on Enterprise Resource Planning (ERP) and organisational dimensions respectively. Nowotarski and Paslawski [17], and Sommer et al. [18] focused on Germany and the construction sector.

In this paper, the objective is to understand the level of SMME readiness/adoption for smart manufacturing and how this has been researched from the perspective of innovation. The rationale for the research objective was derived from Nooteboom [19, 20] and Tornatzky and Klein's [21] work on SMMEs underpinned by Roger's diffusion of innovations theory [22]. Building on the diffusion of innovation theory [22], Nooteboom [19, 20] identified the first stage of the SMME adoption process as awareness; adequate knowledge about the innovation to be adopted. While awareness is generally a given for large firms and technology-oriented SMMEs, it is a key barrier for technology-following and non-technological SMMEs with regard to readiness for adoption [19, 20, 23].

The adoption and diffusion of new technological innovations is contingent on three characteristics: the relative advantage (benefits) of the technological innovation, the complexity of the technological innovation and the compatibility of the technological innovation [21]. Relative advantage is the degree to which an innovation is perceived as being better than the idea it supersedes, complexity is the degree to which an innovation is perceived as relatively difficult to understand and use, while compatibility is the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters [21].

The systematic review specifically focuses on the context of the research (low-income or high-income country), the awareness (adequate knowledge), benefits (relative advantage), the technological innovations and readiness/adoption as important dimensions of interest. Based on the objective this review differentiates itself from previous similar reviews [5, 13–18].

The paper therefore sought to find answers from the review for the following research questions (RQ):

RQ1: What is the state of awareness (adequate knowledge) of SMMEs in relation to smart manufacturing?
RQ2: What are the benefits of smart manufacturing in relation to SMMEs?
RQ3: Which technologies are seen as key to the concept of smart manufacturing in relation to SMMEs?
RQ4: What is the state of smart manufacturing readiness and adoption by SMMEs?

The rest of the paper is structured as follows, section 2 presents the review methodology. Section 3 presents the results of the review and the research gaps. The conclusions, limitations and future work are presented in Section 4.

2 Methodology

The study followed Lage and Junior's [24] systematic review protocol, and used the reporting approach of Amui et al's [25]. The SLR considered publications, which followed the formal introduction of Industry 4.0 that is from 2011 onwards. The time period for article selection was October 2018 to January 2019, while the analysis of the articles was from February 2019 to July 2019. A schematic representation of the adopted review protocol is shown in Figure 1 below.

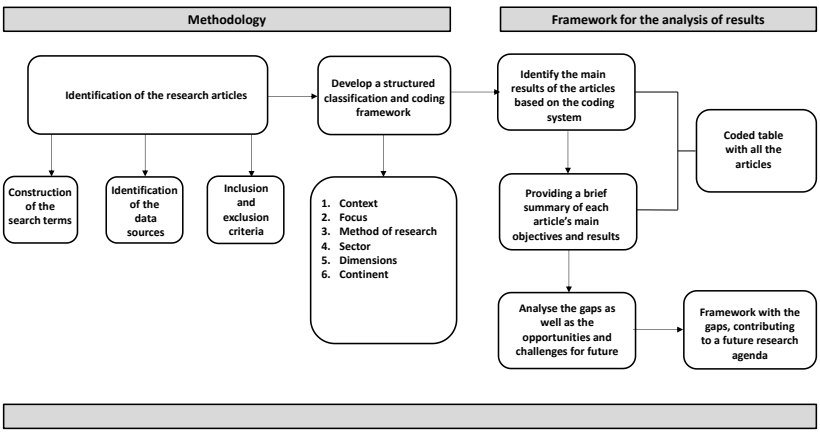

Fig. 1. A schematic representation for the adopted methodology and results framework for this study

2.1 Identification of the Research Articles

The first step was identifying the research articles through; (1) the construction of the search terms, (2) identifying the relevant data sources and (3) inclusion and exclusion criteria.

2.2 Construction of the Search Terms.

The construction of the search terms was primarily derived from RQ1, RQ2, RQ3 and RQ4. These search strings were constructed based on the *Unit of Analysis* (SMMEs),

Technology Artefact (Smart Manufacturing/Industry 4.0/Smart Factory) and *Phenomenon of Interest* (Adoption/Trends/Benefits/Technologies/Issues). The full details of the 33 constructed search strings are presented in Appendix 1 found on http://dx.doi.org/10.13140/RG.2.2.19652.17285.

2.3 Identification of the Data Sources

Smart Manufacturing (industry 4.0) is based on the convergence of various technologies and the integration of multiple disciplines and domains such as mechanical engineering, electrical engineering, computer science and other related fields [1, 26]. The multidisciplinary nature of smart manufacturing meant that the review needed to perform the search in similar multidisciplinary research databases. The study therefore chose the four that are most commonly used by multidisciplinary researchers [27–33]; Web of Science (WoS), Academic Search Premier (ASP), ScienceDirect and Google Scholar.

2.4 Inclusion and Exclusion Criteria

Using the constructed search terms, 279 articles were identified from the four databases (Figure 2) in the first iteration. This first iteration was based on the following inclusion criteria:

- Articles that mention smart manufacturing or industry 4.0 or smart factory within their content or title
- All industries or sectors (not just manufacturing)
- Peer reviewed journal or conference articles
- Articles written in English

In the second iteration, after removing duplications from different databases, 177 articles were excluded based on the review of titles and abstract. These articles were excluded based on the following exclusion criteria:

- Articles that merely mention some of the search terms, but do not solely focus on smart manufacturing, industry 4.0 or smart factory concepts
- Articles focusing on one specific application of a particular technology in relation to smart manufacturing or industry 4.0 or smart factory
- Articles that do not focus on SMMEs
- Articles that merely mention SMMEs

In the final round of the iteration process, 72 articles were excluded based on the analysis of the full text of the articles. The remainder of the articles (30 peer reviewed journals and conference papers) were determined to be relevant for this review (See Appendix 2 Table 10 on http://dx.doi.org/10.13140/RG.2.2.19652.17285 for the articles selected for this review). The primary exclusion criteria was the following:

- Articles that do not discuss any of the four study dimensions (awareness: adequate knowledge, benefits, technologies and readiness/adoption) discussed in section 1 within their content

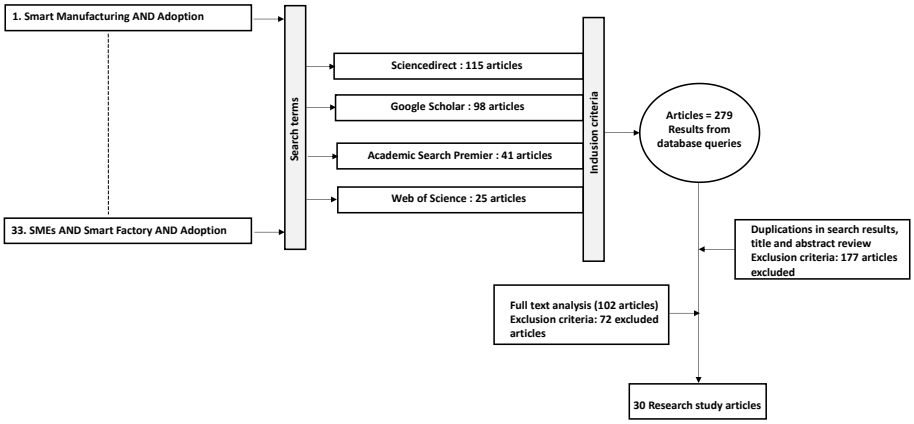

Fig. 2. A schematic representation of the inclusion and exclusion process

2.5 A Structured Classification and Coding Framework

To enable a structured and effective analysis of the body of knowledge contained within the sourced articles, a modified classification and coding framework utilizing numbers and letter codes to classify the articles was utilized (Table 1). This framework is adopted from Amui et al [25] who developed it based on other systematic review efforts [34–38].

Table 1. Classification and Coding Framework

Classification	Description	Codes
Context	High-income countries	1A
	Low-income countries	1B
	Not Applicable	1C
Focus	Smart Manufacturing (SM) as the main theme	2A
	Industry 4.0 (I4.0) as the main theme	2B
	Smart Factory (SF) as the main theme	2C
	SM/I4.0/SF used interchangeably	2D
Method	Qualitative	3A
	Quantitative	3B
	Theoretical	3C
	Empirical	3D
	Case studies/interviews	3E
	Survey	3F
Sector	Manufacturing	4A
	Other Sectors	4B
	Not Applicable	4C
Dimensions	**Awareness(Knowledge)**	5A
	Benefits	5B
	Technologies	5C
	Readiness/Adoption	5D
Origin (Continents)	America	6A
	Europe	6B
	Asia	6C
	Oceania	6D
	Africa	6E

3 Analysis and discussion of findings

The thirty selected research articles were coded according to Table 1, with the resultant coding results shown in Table 2 below.

Table 2. Results of the Codification Framework

	Authors	Context		Focus						Method						Sector		Dimensions				Origin (Continents)			
#1	Mittal et al. (2018a)		1C	2A	2B	2C	2D			3C				4A			5D			5A		6A			
#2	Ganzarain and Errasti (2016)	1A			2B	2C	2D				3D					4C	5D			5A	6B				
#3	Mittal et al. (2018b)		1C	2A	2B	2C	2D			3C		3E		4A			5D	5C				6A			
#4	Mittal et al. (2018c)		1C	2A	2B		2D			3C		3E		4A			5D	5C				6A			
#5	Hamidi et al. (2018)	1B			2B	2C	2D		3B				3F			4C	5D	5C		5A			6C		
#6	Wang et al. (2016)	1A			2B						3D			4A			5D				6B				
#7	Moeuf et al. (2018)		1C		2B	2C	2D			3C						4C	5D	5C			6B				
#8	Dassisti et al. (2018)		1C	2A	2B		2D					3E				4C	5D			5A	6B				
#9	Andulkar et al. (2018)	1A			2B	2C	2D	3A	3B			3E	3F			4C	5D	5C	5B	5A	6B				
#10	Hamzeh et al. (2018)	1A		2A	2B		2D						3F	4A			5D		5B	5A			6D		
#11	El Hamdi et al. (2018)		1B	2A	2B		2D			3C			3F	4A			5D			5A					6E
#12	Wienbruch et al. (2018)	1A			2B					3C	3D			4A			5D			5A	6B				
#13	Dassisti et al. (2017)	1A			2B							3E		4A			5D			5A	6B				
#14	Bär et al. (2018)	1A		2A	2B	2C	2D	3A		3C		3E		4A			5D	5C	5B		6B				
#15	Jones et al. (2018)	1A			2B	2C	2D					3E		4A			5D	5C		5A	6B				
#16	Colombo et al. (2015)	1A			2B	2C	2D				3D					4C	5D				6B				
#17	Issa et al. (2017)	1A			2B						3D	3E		4A			5D	5C			6B				
#18	Faller and Feldmüller (2015)	1A			2B						3D			4A			5D				6B				
#19	Wank et al. (2016)	1A			2B						3D	3E				4C	5D				6B				
#20	Jäger et al. (2016)	1A			2B	2C	2D					3E	3F			4C	5D				6B				
#21	Polat and Karakuş (2018)	1A			2B	2C	2D					3E		4A			5D			5A			6C		
#22	Nowotarski and Paslawski (2017)		1C		2B	2C	2D			3C					4B		5D				6B				
#23	Sevinç et al. (2018)		1C		2B					3C		3E	3F	4A			5D						6C		
#24	Müller et al. (2018)	1A		2A	2B		2D	3A	3B			3E		4A			5D		5B	5A	6B				
#25	Ludwig et al. (2018)	1A			2B							3E				4C	5D				6B				
#26	Kleindienst and Ramsauer (2015)		1C		2B					3C		3E		4A			5D				6B				
#27	Müller et al. (2017)	1A		2A	2B		2D	3A				3E				4C	5D			5A	6B				
#28	Sommer (2015)	1A			2B					3C		3E				4C	5D			5A	6B				
#29	Modrak et al. (2018)		1C		2B					3C		3E				4C	5D	5C			6B				
#30	Müller and Voigt (2018)		1C		2B				3B				3F			4C	5D	5C	5B		6B				

3.1 Context and Origin

The majority of the articles focused on high-income countries (1A) in comparison to low income countries (1B) as shown in Table 2. The majority of the research studies in relation to smart manufacturing (Table 2) originated from Europe (6B) conducted by German universities and research institutions. Only one study by a Moroccan university originated from the African (6E) continent [16]. See details in Appendix 2 Table 11 on http://dx.doi.org/10.13140/RG.2.2.19652.17285.

The findings suggest that there is a research gap in this regard, and therefore a research opportunity for smart manufacturing for SMMEs in low-income countries, specifically in the African continent. The resource constrained environments of low-income country contexts often results in completely new and contrasting technological innovations as has been shown in the mobile money sector in low-income countries [39].

3.2 What's in a name: Smart Manufacturing vs 4IR

In this study, no article used smart manufacturing (2A) and/or smart factory (2C) as the main theme on their own (Table 3). Both these terms were used interchangeably with Industry 4.0 as shown in Table 3. Industry 4.0 (2B) is also not used interchangeably in this study and seems to be the most preferred term (Table 3). This could be as a result of the majority of the researchers/studies emanating from Germany. The findings suggest that the manufacturing 4IR discourse has primarily been through the lens of Industry 4.0 concept applied in a non-contextual approach to country specific problems and strategic initiatives [16, 40]. However, due to definitional differences of these terms (smart manufacturing/industry 4.0/smart factory) [5], there is a research gap and a related opportunity to contextualize 4IR concepts such as smart manufacturing to country specific problems and strategic initiatives.

Table 3. Usage of the 4IR Terms

4IR Concept	Code	Used as a Main Theme Only	Used as Main Theme and Interchangeably	No. of Articles
Smart Manufacturing (SM)	2A	x	x	
Industry 4.0 (I4.0)	2B	√	x	12
Smart Factory (SF)	2C	x	x	
SM & I4.0	2A + 2B	x	√	6
SM & SF	2A + 2C	x	x	
I4.0 & SF	2B + 2C	x	√	9
SM & I4.0 & SF	2A + 2B + 2C	x	√	3

3.3 Research Methods

The majority of the articles utilized case studies/interviews (3E) as research methods (Table 2). The case studies/interviews were in most cases used as part of the mixed research methodology approach to support conceptual/theoretical research (3C) articles (Table 2). Further analysis on the types of research methods and how they were utilized in the reviewed articles is shown in Table 4. The findings illustrate the need to create new substantive research theories that can contextualize smart manufacturing research to relate better to context specific needs.

Table 4. Research Methods

Research Methods	Qualitative 3A	Quantitative 3B	Theoretical 3C	Empirical 3D	Case Studies/Interviews 3E	Survey 3F	No. of Articles
Single Research Method	x	x	3	4	4	1	13
Mixed Research Method	x	x	9	3	13	6	17
Qualitative	4	x	x	x	x	x	4
Quantitative	x	4	x	x	x	x	4

3.4 Economic Sector

While the majority of the articles (4A) focused on the manufacturing sector, a significant number of articles (4C) studied SMMEs in a generalized manner (Table 5). Although SMMEs share a number of similarities, they are heterogeneous in nature as they operate in different sectors [41].The findings suggest that more sector specific research needs to be done with regards to SMMEs.

Table 5. Economic sector

Economic Sector	Code	No. of Articles
Manufacturing	4A	16
Other sectors	4B	1
Not applicable	4C	13

3.5 Dimensions

To answer the framed research questions posed in section 1 (introduction), the four dimensions (1) awareness (adequate knowledge), (2) benefits (relative advantage), (3) technologies and (4) readiness/adoption (awareness, relative advantage, complexity and compatibility) shown in Table 1, were analyzed in accordance with the codification results of Table 2.

Smart Manufacturing: Awareness (adequate knowledge).
RQ1 sought to establish the state of awareness (knowledge) of SMMEs in relation to smart manufacturing. While the majority of the studies (16 articles) did not mention or discuss this dimension, those articles that did mention/discuss (14 articles) this dimension did not provide any substantive details in relation to the awareness dimension (Table 6). See more details with regard to further analysis in Appendix 2 Table 12 on http://dx.doi.org/10.13140/RG.2.2.19652.17285.

The findings indicates that there is little comprehensive research focusing on investigating SMME levels of awareness in relation to smart manufacturing. Given that the awareness stage has very critical and significant implications to smart manufacturing readiness/adoption based on the innovations theory [19, 22], there is a critical need for research to focus on the awareness of SMMEs in relation to the opportunities, challenges and demands of smart manufacturing.

Table 6. Awareness

Dimension: Awareness	Code	No. of Articles
SMMEs lack awareness of smart manufacturing	5A	10
SMMEs have adequate knowledge of smart manufacturing	5A	4
Not discussed/mentioned	5A	16

Smart Manufacturing (industry 4.0): Relative Advantage (Benefits).
RQ2 sought to identify the benefits (relative advantage) of smart manufacturing in relation to SMMEs. The majority of the research studies did not look into the relative advantage dimension to identify explicitly or implicitly any potential benefits of smart manufacturing for SMMEs (Table 7). Only 5 articles discussed and or identified the relative advantage of smart manufacturing (See details in Appendix 2 Table 13 on http://dx.doi.org/10.13140/RG.2.2.19652.17285).

The findings points to the need for research studies to focus on explicitly identifying the practical relative advantage of smart manufacturing for SMMEs based on concrete and comprehensive research.

Table 7. Benefits (Relative Advantage)

Dimension: Benefits (Relative Advantage)	Code	No. of Articles
Potential benefits for SMMEs explicitely identified	5B	5
Not discussed/mentioned	5B	25

Smart Manufacturing (industry 4.0): Technologies.
RQ3 sought to identify technologies that are seen as key to the concept of smart manufacturing in relation to SMMEs. The majority of the research studies identified and

discussed smart manufacturing technologies from a general applications context and not specific to SMMEs or how they relate and or can be applied in SMME context (Table 8). Only 10 articles identified technologies that are seen as key to the concept of smart manufacturing in relation to SMMEs (See details in Appendix 2 Table 14 on http://dx.doi.org/10.13140/RG.2.2.19652.17285).

The findings reveals a research gap in identifying specific smart manufacturing technologies that are relevant to SMMEs from a sector or industry perspective. This research gap leaves SMMEs exposed and vulnerable to smart manufacturing anecdotes and sales pitches. The availability of empirically proven research on smart manufacturing technologies per sector and or industry would assist SMMEs which usually do not have the resources to do feasibility studies.

Table 8. Technologies

Dimension: Technologies (key to SMMEs)	Code	No. of Articles
Smart manufacturing technologies for SMMEs identified/discussed	5C	10
Not discussed/mentioned	5C	20

Smart Manufacturing (industry 4.0): Readiness/Adoption.

RQ4 sought to understand the state of smart manufacturing readiness and adoption by SMMEs based on the innovations theory [19, 22]. Readiness and adoption of smart manufacturing by SMMEs is contingent on four key dimensions (1) awareness (adequate knowledge), (2) relative advantage (benefits), (3) complexity and (4) compatibility [19, 22]. Only a few research articles looked into the issue of awareness (Table 6), relative advantage (Table 7) and complexity as shown in Table 9, while 90% of the research articles indicates that smart manufacturing is currently incompatible with SMME characteristics due to lack of expertise, skills and resources (Table 9). See detailed analysis of complexity and compatibility in Appendix 2 Table 15 on http://dx.doi.org/10.13140/RG.2.2.19652.17285.

The findings reveal that, research gaps in relation to understanding the impact of awareness, relative advantage and complexity needs to be addressed to be able to assess the state of smart manufacturing readiness and adoption by SMMEs. The findings, further reveal that compatibility seems to be emerging as one of the major factors negatively affecting smart manufacturing readiness/adoption for SMMEs. This situation may have far reaching implications in the context of low-skilled and resource constrained low-income countries.

Table 9. Adoption/Readiness

Dimension: Adoption/Readiness	No. of Articles	Percentage (total articles)
SMMEs have adequate knowledge of smart manufacturing	4	13
Potential benefits for SMMEs explicitely identified	5	17
Smart Manufacturing is complex for SMMEs to understand	11	37
Smart manufacturing is incompatible with SMME characteristics	27	90

4 Conclusion, Limitations and Future Work

The primary objective of this work was to understand the level of SMME readiness/adoption for smart manufacturing and how this has been researched from the per-

spective of digital technologies innovation guided by four research questions (introduction section). Firstly, the findings suggest that smart manufacturing research on SMMEs is limited in low-income countries and also not contextualized to context specific demands such as sector and or industry specific challenges and preconditions. These includes smart manufacturing technology applications and how they relate or can be applied in SMME context. Secondly, the findings suggest that the issues of SMME awareness, relative advantage and complexity of smart manufacturing DT innovation have received very little research attention. This is critical for readiness/adoption in relation to technology-following SMMEs [20]. Lastly, SMME characteristics (lack of skills, expertise and resources) are incompatible with smart manufacturing. This renders technology-following SMMEs not ready for the adoption of smart manufacturing.

Future context specific research investigating smart manufacturing in settings such as resource constraint low-income countries, non-technology based sectors/industries such as the manufacturing and technology-following SMMEs is recommended. More research to evaluate the impact of SMME awareness, relative advantage, complexity and incompatibility of smart manufacturing for former non-technology (but now technology-following) SMMEs should also be considered in future studies.

The systematic review is limited in its time horizon and its emphasis on low-income/ high-income context. Further research is needed that uses other regional aspects.

References

1. Kang, H.S., Lee, J.Y., Choi, S., Kim, H., Park, J.H., Son, J.Y., Kim, B.H., Noh, S. Do: Smart manufacturing: Past research, present findings, and future directions. Int. J. Precis. Eng. Manuf. - Green Technol. 3, 111–128 (2016). doi:10.1007/s40684-016-0015-5
2. Riddick, F., Wallace, E., Davis, J.: Variability in Food Production. J. Res. Natl. Inst. Stand. Technol. 121, 17–32 (2016). doi:10.6028/jres.121.002
3. Issa, A., Hatboglu, B., Bildstein, A., Bauernhansl, T.: Industry 4.0 roadmap: Framework for digital transformation based on the concepts of capability maturity and alignment. Procedia CIRP. 72, 973–978 (2018). doi:10.1016/j.procir.2018.03.151
4. Zhong, R.Y., Xu, X., Klotz, E., Newman, S.T.: Intelligent Manufacturing in the Context of Industry 4.0: A Review. Engineering. 3, 616–630 (2017). doi:10.1016/J.ENG.2017.05.015
5. Mittal, S., Khan, M.A., Romero, D., Wuest, T.: A critical review of smart manufacturing & Industry 4.0 maturity models: Implications for small and medium-sized enterprises (SMEs). J. Manuf. Syst. 49, 194–214 (2018). doi:10.1016/j.jmsy.2018.10.005
6. Thoben, K.-D., Wiesner, S., Wuest, T.: "Industrie 4.0" and Smart Manufacturing – A Review of Research Issues and Application Examples. Internantional J. Autom. Technol. 11, 4–19 (2017). doi:10.20965/ijat.2017.p0004
7. Mittal, S., Khan, M.A., Wuest, T.: Smart manufacturing: Characteristics and technologies. IFIP Adv. Inf. Commun. Technol. 492, 539–548 (2016). doi:10.1007/978-3-319-54660-5_48
8. Davis, J., Edgar, T., Porter, J., Bernaden, J., Sarli, M.: Smart manufacturing,

manufacturing intelligence and demand-dynamic performance. Comput. Chem. Eng. 47, 145–156 (2012). doi:10.1016/j.compchemeng.2012.06.037

9. Jun, C., Yeon, J., Yoon, J., Hyun, B.: Applications ' Integration and Operation Platform to Support Smart Manufacturing by Small and Medium-sized Enterprises. Procedia Manuf. 11, 1950–1957 (2017). doi:10.1016/j.promfg.2017.07.341
10. Müller, J.M., Voigt, K.A.I.I.: Industry 4.0 - Integration Strategies for Small and Medium - Sized Enterprises. IAMOT 2017 Conf. Proc. (2017)
11. Safar, L., Sopko, J., Bednar, S., Poklemba, R.: Concept of SME Business Model for Industry 4 . 0 Environment. TEM J. 7, 626–637 (2018). doi:10.18421/TEM73-20
12. Luff, P.: The 4 th Industrial Revolution and SMEs in Malaysia and Japan : Some Economic , Social and Ethical Considerations. 25, 25–48 (2017)
13. Mittal, S., Romero, D., Wuest, T.: Towards a Smart Manufacturing Maturity Model for SMEs (SM3E). 1, (2018)
14. Mittal, S., Romero, D., Wuest, T.: Towards a Smart Manufacturing Toolkit for SMEs. 1, 155–163 (2018). doi:10.1007/978-3-319-99707-0_20
15. Moeuf, A., Pellerin, R., Lamouri, S., Tamayo-giraldo, S., Moeuf, A., Pellerin, R., Lamouri, S., Tamayo-, S.: The industrial management of SMEs in the era of Industry 4 . 0. Int. J. Prod. Res. 7543, 0 (2018). doi:10.1080/00207543.2017.1372647
16. Hamdi, S.E.L.: Disposition of Moroccan SME Manufacturers to Industry 4 . 0 with the implementation of ERP as a first step. 2018 Sixth Int. Conf. Enterp. Syst. 116–122 (2018). doi:10.1109/ES.2018.00025
17. Piotr Nowotarski, Jerzy Paslawski: Industry 4 . 0 Concept Introduction into Construction SMEs. In: IOP Conference Series: Materials Science and Engineering (2017)
18. Sommer, L.: Industrial Revolution - Industry 4.0:Are German Manufacturing SMEs the First Victims of this Revolution? J. Ind. Eng. Manag. 8, 1512–1532 (2015)
19. Nooteboom, B.: Innovation and Diffusion in Small Firms: Theory and Evidence. Small Bus. Econ. 6, 327–347 (1994). doi:10.1007/bf01065137
20. Nooteboom, B., Coehoorn, C., Van Der Zwaan, A.: The Purpose and Effectiveness of Technology Transfer to Small Businesses by Government-sponsored Innovation Centres. Technol. Anal. Strateg. Manag. 4, 149–166 (1992). doi:10.1080/09537329208524089
21. Tornatzky, L.., Klein, K.: Innovation characteristics and innovation adoption-implementation: A meta-analysis of findings. IEEE Trans. Eng. Manag. 29, 28–43 (1982). doi:10.1109/TEM.1982.6447463
22. Rogers, E.M.: Difiusion of innovations. New York Free Press. (1983)
23. Gumbi, L.N., Mnkandla, E.: Investigating South African Vendors' Cloud Computing Value Proposition to Small, Medium and Micro Enterprises: A Case of the City of Tshwane Metropolitan Municipality. African J. Inf. Syst. 7, 1936–282 (2015)
24. Lage Junior, M., Godinho Filho, M.: Variations of the kanban system: Literature review and classification, (2010)
25. Amui, L.B.L., Jabbour, C.J.C., de Sousa Jabbour, A.B.L., Kannan, D.: Sustainability as a dynamic organizational capability: a systematic review and a future agenda toward a sustainable transition. J. Clean. Prod. 142, 308–322 (2017). doi:10.1016/j.jclepro.2016.07.103

26. Thoben, K.-D., Wiesner, S., Wuest, T.: "Industrie 4.0" and Smart Manufacturing – A Review of Research Issues and Application Examples. Int. J. Autom. Technol. 11, 4–16 (2017). doi:10.20965/ijat.2017.p0004
27. Yang, H., Tate, M., Mary Tate, V.: A Descriptive Literature Review and Classification of Cloud Computing Research. 31, 35–60 (2012)
28. Fahim El-Gazzar, R.: IFIP AICT 429 - A Literature Review on Cloud Computing Adoption Issues in Enterprises. 214–242 (2014)
29. Osman Adam, I., Musah, A.: Small and Medium Enterprises (SMEs) in the Cloud in Developing Countries: A Synthesis of the Literature and Future Research Directions. J. Manag. Sustain. 5, (2015). doi:10.5539/jms.v5n1p115
30. Asatiani, A.: Why Cloud? -A Review of Cloud Adoption Determinants in Organizations. In: Twenty-Thrid ECIS 2015. pp. 1–17 (2015)
31. Attard, J., Orlandi, F., Scerri, S., Auer, S.: A systematic review of open government data initiatives. Gov. Inf. Q. 32, 399–418 (2015). doi:10.1016/j.giq.2015.07.006
32. Jacsó, P.: The plausibility of computing the h-index of scholarly productivity and impact using reference-enhanced databases. Online Inf. Rev. 32, 266–283 (2008). doi:10.1108/14684520810879872
33. Shah, S.R.U., Mahmood, K.: Review of Google scholar, Web of Science, and Scopus search results: The case of inclusive education research. Libr. Philos. Pract. 1544 (2017)
34. Fahimnia, B., Sarkis, J., Davarzani, H.: Green supply chain management: A review and bibliometric analysis, (2015)
35. Junior, M.L., Filho, M.G.: Production planning and control for remanufacturing: literature review and analysis. Prod. Plan. Control. 23, 419–435 (2012). doi:10.1080/09537287.2011.561815
36. Jabbour, C.J.C.: Environmental training in organisations: From a literature review to a framework for future research. Resour. Conserv. Recycl. 74, 144–155 (2013). doi:10.1016/j.resconrec.2012.12.017
37. Jabbour, C.J.C., Jugend, D., De Sousa Jabbour, A.B.L., Gunasekaran, A., Latan, H.: Green product development and performance of Brazilian firms: Measuring the role of human and technical aspects. J. Clean. Prod. 87, 442–451 (2015). doi:10.1016/j.jclepro.2014.09.036
38. Mariano, E.B., Sobreiro, V.A., Rebelatto, D.A. do N.: Human development and data envelopment analysis: A structured literature review. Omega. 54, 33–49 (2015). doi:10.1016/j.omega.2015.01.002
39. Kim, M., Zoo, H., Lee, H., Kang, J.: Mobile, Financial Inclusion and Development: A Critical Review of Academic Literature. GlobDev. (2017)
40. Hamidi, S.R., Aziz, A.A., Shuhidan, S.M., Aziz, A., Mokhsin, M.: SMEs Maturity Model Assessment of IR4 . 0 Digital Transformation. In: International Conference on Kansei Engineering & Emotion Research. pp. 721–732 (2018)
41. Alshamaila, Y., Papagiannidis, S., Li, F.: Cloud computing adoption by SMEs in the north east of England. J. Enterp. Inf. Manag. 26, 250–275 (2013). doi:10.1108/17410391311325225