



AGILITY AND FLEXIBILITY STRATEGIES IN MANUFACTURING SYSTEMS: A SYSTEMATIC REVIEW WITH A FOCUS ON SUB-SAHARAN AFRICA

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ABSTRACT

Special companies, those in markets with fluctuating demand and supply, need to take the ups and downs in the market, disruption in their supply chains, and the technology and competitive pressure, and still maintain delivery, quality, and cost targets. The present systematic review, following the PRISMA 2020 guidelines, aims at gathering 42 studies related to the manufacturing agility and flexibility, focusing on Sub Saharan Africa (SSA). The corpus consists of manufacturing flexibility, agile and leagile manufacturing, lean practice, supply-chain agility, digital transformation and Industry 4.0 and is segmented based on application domain, geography, methodology and publication period. The evidence suggests that agility and flexibility are associated with improved operational and organisational performance in SSA, but the pathways and degree of application varies significantly between firms and countries. The consistent challenges are cost, skills, infrastructure (reliability of power supply) and supply chain; management commitment is always cited as the final key. Digital technologies and Industry 4.0 are enablers that require a combination of infrastructure, organisational integration and human capability, and not just ownership of digital technology. There is some fragmentation in measurement of agility – different constructs are used in various surveys, there are formal agility indices, and new AI-assisted assessment frameworks are emerging – none of which have yet been validated for SSA. A series of shop-floor studies in Zimbabwe (process-parameter optimisation, data-driven maintenance, and agent-based condition monitoring) demonstrates that new capabilities at the operational level can be realized at relatively low costs, but are rarely related to the strategic agility literature. The conceptual framework and research agenda of the review call for a SSA-specific measurement tool, an integrated socio-technical model, operational as well as longitudinal evidence, and more robust mechanisms of building industry-academy capabilities, e.g., learning factories.

Keywords: Manufacturing Agility; Manufacturing Flexibility; Lean Manufacturing; Industry 4.0; Sub-Saharan Africa; Systematic Review; PRISMA

1 INTRODUCTION

Manufacturers operate in an environment where customers' needs change, demand is volatile, technology advances, supply chains are broken, and competition is growing. Agility is the ability to sense and respond quickly and effectively to change; flexibility is about the ability to absorb variation in products, processes, volumes and resources. Early

research on agile manufacturing emphasised the need for the firms to be responsive, flexible and act coordinated (Gunasekaran, 1998; Yusuf, Sarhadi and Gunasekaran, 1999); later, Abdelilah, El Korch and Balambo (2018) explained that flexibility and agility are not synonymous but complementary.

The focus has since been extended to include digital transformation, Industry 4.0, the capacity of the workforce, the resilience of supply chains and organisational change. The expansion is particularly important in Sub-Saharan Africa (SSA), where companies are often hindered in their investment, their skills, their connectivity, in the development of their infrastructure and in the use of technology. However, evidence from South Africa, Zimbabwe, Ghana, Nigeria, Uganda, Kenya, Ethiopia and Tanzania suggests that there are other contextual factors that influence manufacturing adaptation, and not just technology (Maisiri, Van Dyk and Coetzee, 2021; Peter, Pradhan and Mbohwa, 2023; Muhla et al., 2025a; Matindana, Sinkamba and Mgwatu, 2025). Labour-intensive, and relatively inflexible, approaches have been identified as the basis for Zimbabwe local manufacturers, though the slow uptake of technology has been attributed to long economic instability (Muhla et al., 2023).

The current reviews either give agility a generic definition based on the evidence from the industrialised countries or discuss a single enabling factor, such as Industry 4.0, as an isolated phenomenon (Achieng and Malatji, 2022). No current one overall record of the agility and flexibility strategies actually adopted by SSA manufacturers, their limitations, the way agility is measured, how new technologies are influencing them. This review aims to fill the void. It categorises the literature based on its application domain, geographical location, methodology and publication period; compares reported strategies and barriers; explores measurement approaches and examines the role of digital and Industry 4.0 technologies.

It is guided by four research questions:

- RQ1: What agility and flexibility strategies have been documented in manufacturing firms in Sub-Saharan Africa?
- RQ2: Which region-specific barriers, for example infrastructure, supply-chain, technology-access and skills constraints, affect the adoption of these strategies?
- RQ3: What methods or frameworks are used to measure manufacturing agility, and how do they compare between SSA and global contexts?
- RQ4: What role do emerging technologies (automation, digital tools and Industry 4.0) play in achieving manufacturing agility in SSA, and where does this question remain inadequately addressed?

The review offers three contributions: (i) an organized taxonomy of the existing literature on SSA agility and flexibility; (ii) a conceptual framework that brings together literature on environmental change, organisational sensing and response, manufacturing flexibility and sustained agility under SSA contextual moderators; and (iii) a research agenda that connects strategic agility research (based on surveys) with the avalanche of operational, shop-floor evidence emerging from the region.

2 BACKGROUND AND THEORETICAL BASIS

2.1 Manufacturing flexibility and agility

Manufacturing flexibility is the ability of a manufacturing system to adjust its product, quantity, process, machines and operating conditions without affecting the performance of the system. It enables companies to control fluctuations in order volumes and product lines and delivery schedules. Manufacturing agility is more encompassing which is the ability to be both flexible and responsive in the face of internal and external change, such as a change in demand, disruption of supply chain, and new technology, by using flexibility and responsiveness to the change together and in coordinated action (Gunasekaran, 1998; Yusuf, Sarhadi and Gunasekaran, 1999).

As pointed out by Abdelilah, El Korch and Balambo (2018), there is a relationship between the two concepts but they are not exactly the same and flexibility is linked to the possibility of adapting while agility is associated with rapid and effective response. In Zimbabwe, agility has been defined as the capability of an organisation to reinvent itself in the face of environmental uncertainty and to be successful in that process, its chief mission is to respond to customer needs and market demands in time to make the best of the short-lived windows of opportunity (Muhla et al., 2023).

The distinction is played out in practice as can be seen in other studies across SSA. The works by Nagaaba (2021, 2022) and Fofana, Nyarko and Takyi (2021) and Fofana et al. (2023) explore agile and leagile manufacturing in Ugandan small and medium sized factories, and flexible manufacturing systems in African manufacturing companies respectively. The studies demonstrate flexibility is not just equipment related but also for production practices, workforce deployment, sourcing and organisational decision-making. There is also a level of flexibility within each process. The optimum

cutting parameters for surface quality and energy consumption were found to be different between teak, saligna and pine in the experimental work conducted in Zimbabwean workshops, which means that such a planing operation must be re-optimised if the material mix changes (Tayisepi et al., 2023). The same applies to the local variation in raw material for edible-oil production; the bleaching stage was modified by using process settings, which were established through experimentation (Jansen et al., 2025). These findings suggest that the engineering flexibility of materials and processes can be developed only if it is done deliberately and not just acquired via equipment.

2.2 The relationship between flexibility and agility

Flexibility is the enabler of agility, but it is not the same. A firm can have great flexibility in its equipment or product portfolio, but still react slowly, and/or be unable to activate resources or coordinate the supply chain. In contrast, an organisation can become agile to respond even if it isn't physically flexible. The literature thus calls for a systems perspective that focuses on the interaction between equipment, information, people, processes and the relationships along the supply chain (Gunasekaran, 1998; Abdelilah, El Korchi and Balambo, 2018). The survey results from Zimbabwe corroborate this, as some of the technologies required for agility were available within a firm, but what was lacking was interconnection and optimisation of the technologies (Muhla et al., 2023).

2.3 Digital manufacturing and Industry 4.0

Although Industry 4.0 increases information availability, connectivity, monitoring and decision support, adoption across SSA is not even. The study conducted by Muhla et al. (2025a) revealed that the dominant technologies in use by the Zimbabwean manufacturers are mainly fundamental technologies like sensors, PLCs, mobile devices and internet connectivity, whereas technologies like additive manufacturing, simulation and mathematical modelling are not very common.

Maisiri et al. (2021) give an overview of barriers to sustainable adoption in South Africa, and Peter et al. (2023) assess Industry 4.0 concepts among small and medium businesses (SMEs) in South Africa. Recent research indicates that the use of digital technologies becomes most effective when used in conjunction with human capital and knowledge management and organisational practice – and not as standalone solutions (Tran et al., 2026; Zhang, Telila and Jima, 2026). The area showcases applied studies that illustrate locally designed digital capability.

A multi-agent condition-monitoring system for an induction furnace installed in a cable manufacturer in Zimbabwe, from a Siemens S7-1200 PLC, an OPC server and open-source JADE agents, successfully detected all five fault categories for the 72 hours test without any false-positive detections and had a reduced payback period of three months (Mashava et al., 2026). A coal-fired power station random-forest preventive-maintenance model revealed that corrective maintenance jobs made up approximately 72% of maintenance jobs, and a reliability operating point associated with higher availability and lower predicted cost (Senda et al., 2026). The cases demonstrate that commercial off-the-shelf components and open source frameworks can provide Industry 4.0 functions within investment portfolios that can be accessed by medium-sized SSA companies.

2.4 Lean, supply-chain, workforce and SSA context

Manufacturing responsiveness is closely related to lean manufacturing and supply-chain agility. Lean methods act to stabilise and smooth processes, while the agility of the supply chain enables a firm to respond to external changes. In Ghana, the measures of flexibility and operations-management have been correlated to procurement performance (Agbeka et al., 2025). There has been research on agility across the strategic, market sensing, workforce and supply-chain aspects in Kenya, Nigeria and South Africa (Bassey, Uwa and Okurebia, 2023; Gates and Mengyun, 2024; Njenga and Mang'ana, 2026; Okeke and Bello, 2026), while in Tanzania, the drivers of lean adoption and value-stream mapping in food processing have been explored (Matindana and Sinkamba, 2025; Matindana, Sinkamba and Mgwatu, 2025).

The workforce dimension tends to be under-weighted. Unsafe practices, fatigue, stress and cognitive overload are significant factors in Zimbabwean manufacturing contributing to workplace injuries, while management support, awareness and training represent the primary challenges in implementing human-factors interventions (Muhla et al., 2025b). Low-cost design can also be used to enhance physical capability: an upper-limb passive exoskeleton for construction workers and industrial workers to improve agility was explicitly inspired by the fact that physical agility can be improved through ergonomic design, and was demonstrated as being less costly than imported alternatives at approximately US\$387 (Tandi et al., 2025).

SSA context is important because the effectiveness of any strategy is dependent on infrastructure, skills availability, financial resources and supply-chain conditions. Often cited is unreliable electricity, with small scale renewable energy alternatives like vertical axis wind turbines that capture the downwash from passing traffic, being demonstrated locally to lessen reliance on an unstable electricity grid (Muyambo et al., 2025). This review thus considers agility as a system ability influenced by the business context of the firm.

2.5 Conceptual framework of the review

Manufacturing agility is defined as a system-level ability to adjust – enabling by manufacturing flexibility and a combination of other organisational, technological, operational and supply-chain capabilities. In Figure 1, we can see that the turbulence of the environment triggers the following processes: sensing (information collection), deciding (information interpretation and coordination) and mobilising (deployment of resources, people and suppliers). The organisational responses to these are realised in manufacturing flexibility and reconfiguration to create ongoing agility, while the outcomes contribute to organisational learning. The enablers (digital technology, lean practice, workforce capability, supplier relationships) support each step and the contextual conditions of the SSA moderate the reach of each step. Both flexibility and Agility as realised response are based on the agile-manufacturing literature (Gunasekaran, 1998; Yusuf, Sarhadi and Gunasekaran, 1999; Abdelilah, El Korchi and Balambo, 2018).

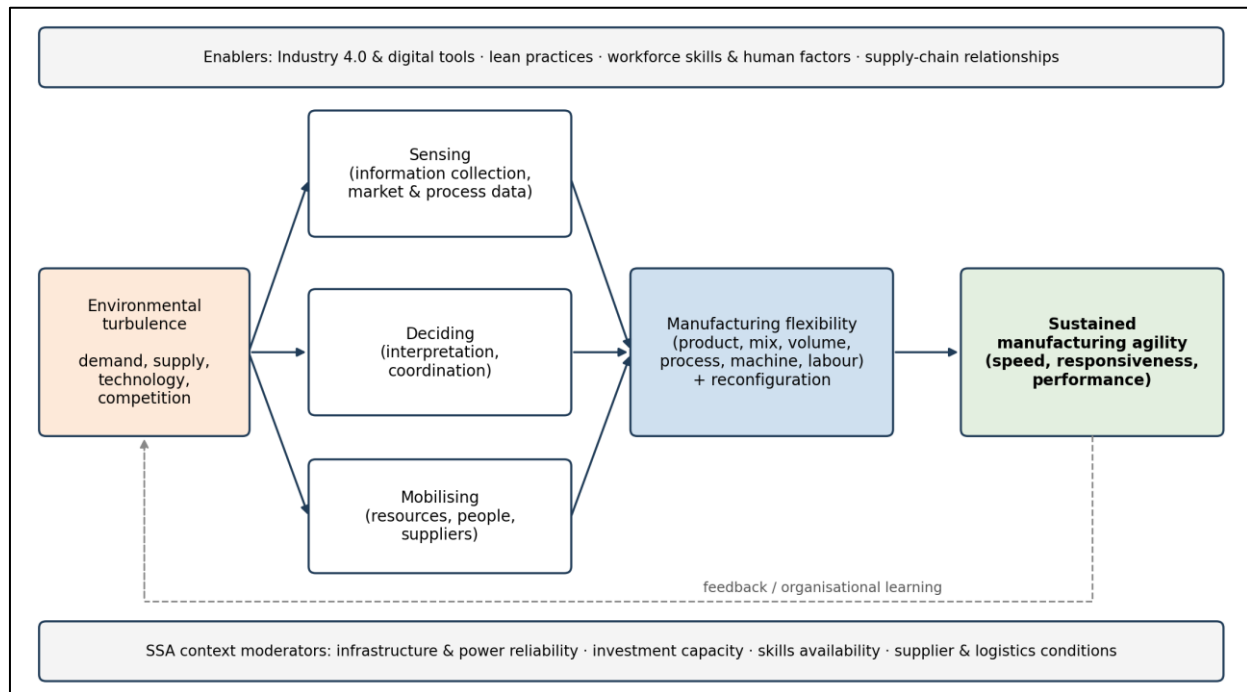


Figure 1: Conceptual framework of the review: from environmental turbulence to sustained manufacturing agility. Source: authors' own elaboration, informed by Gunasekaran (1998), Yusuf, Sarhadi and Gunasekaran (1999) and Abdelilah, El Korchi and Balambo (2018).

3 METHODOLOGY

3.1 Review design

The review was conducted using a systematic literature review design, and reported following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement (Page et al., 2021). The four research questions were determined prior to the screening and the inclusion and exclusion criteria were established. The included studies were methodologically heterogeneous, and used non-equivalent constructs, so the evidence was synthesized using a structured narrative approach.

3.2 Information sources and search strategy

A search was performed in Scopus, Web of Science, IEEE Xplore and Google Scholar. The two main search terms used were: "manufacturing agility" OR "agile manufacturing" OR "flexible manufacturing" OR "manufacturing flexibility" AND ("Sub-Saharan Africa" OR "developing countries" OR "emerging economies" OR Africa) NOT ("agile software" OR Scrum OR "software development"). A secondary string was used: ("manufacturing agility" OR "agile manufacturing" OR "flexible manufacturing") AND (Africa OR "developing countr*"). Records retrieved were entered into a common review tracker.

3.3 Eligibility criteria

The time frame for the search was from January 2016 through September 2026. Three old articles published prior to 2016 (Gunasekaran, 1998, Yusuf, Sarhadi and Gunasekaran, 1999, Routroy, Potdar and Shankar, 2015) and one old empirical paper by SSA (Acquaah and Amoako-Gyampah, 2003) were kept as baseline references. The study if it covered

manufacturing agility, manufacturing flexibility, lean/agile practice, supply-chain agility, digital manufacturing or Industry 4.0 in manufacturing or a closely-related industrial application, was included. To help interpret the SSA evidence, comparator studies from global and developing-economy contexts were included. Data from outside of manufacturing or agility, including apparel trade, agile software workforces, non-peer-reviewed policy papers and construction project management were not included.

3.4 Study selection

Titles and abstracts were independently reviewed by two reviewers and differences in eligibility were discussed and solved by a third reviewer when necessary. A total of 46 records were identified, no duplicates were found, 46 were screened and four were excluded at screening, and 42 full-text studies were assessed and included (Figure 2). This flow is used throughout the taxonomy, synthesis and conclusions.

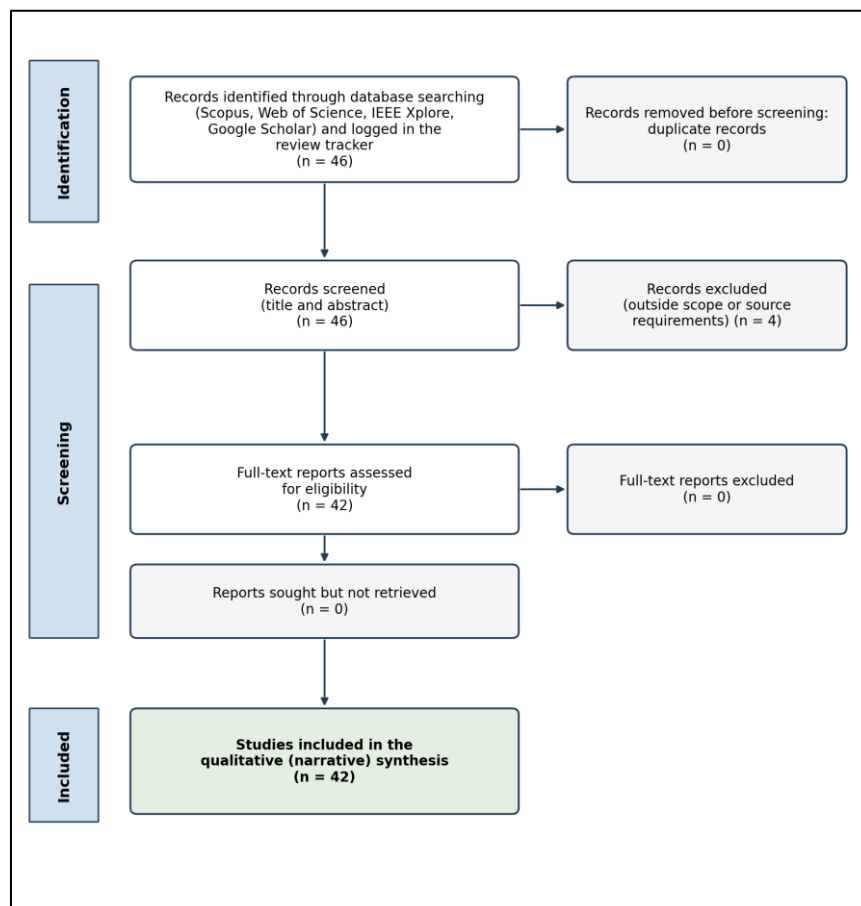


Figure 2: PRISMA flow diagram of study identification, screening and inclusion. Adapted from the PRISMA 2020 flow diagram template (Page et al., 2021), licensed under CC BY 4.0.

3.5 Data extraction and synthesis

The data was collected using a standard data extraction sheet that captured bibliographic information, country, sector, firm size, research design, agility or flexibility construct, measurement approach, barriers reported, technologies and main findings. For each study, one application domain of the taxonomy (Section 4) was selected as primary and each study was coded for the research question(s) it answered. Comparisons were made between the findings within the different domains and regions to gain an understanding of any commonalities, discrepancies and missing data.

3.6 Supporting literature

Apart from the 42 studies included, the discussion relies on some supporting engineering studies from the region, primarily from Zimbabwe, namely optimisation of process parameters, maintenance, condition monitoring, human factors, assistive technology, energy technologies and engineering education. The studies that do not focus on agility as a construct are not included in the synthesis corpus or counts of the tables (1-4). They are referred to illustrate the way in which operational capabilities, which are the foundations for flexibility, are being built in SSA and to provide a basis for the research agenda.

4 CLASSIFICATION AND TAXONOMY

Each of the 42 studies received one primary classification, so each table below totals 42. The categories indicate the principal analytical function of each study and do not imply that a paper addresses only one research question.

Table 1: Classification by application domain

Application domain	Description	RQ alignment	No. of studies	Representative sources
A. Theoretical and conceptual foundations	Definitions, conceptual distinctions and foundational agile-manufacturing ideas	Background	3	Gunasekaran (1998); Yusuf et al. (1999); Abdelilah et al. (2018)
B. SSA agility and flexibility strategies	Firm-level strategies, practices and capabilities for agility and flexibility	RQ1	19	Nagaaba (2021, 2022); Fofana et al. (2021, 2023); Muhla et al. (2023); Bassey et al. (2023); Agbeka et al. (2025); Njenga and Mang'ana (2026)
C. Region-specific barriers and context	Skills, infrastructure, investment, supply-chain and contextual constraints	RQ2	3	Acquaah and Amoako-Gyampah (2003); Maisiri et al. (2021); Mechali et al. (2025)
D. Technology and Industry 4.0 enablement	Digitalisation, smart manufacturing, automation and Industry 4.0	RQ4	5	Peter et al. (2023); Muhla et al. (2025a); Eziashi et al. (2026); Zhang et al. (2026)
E. Measurement and framework studies	Agility indices, readiness models and formal assessment frameworks	RQ3	4	Routroy et al. (2015); Nagaaba (2022); Ali et al. (2026); Ren (2026)
F. Global and developing-economy comparators	Non-SSA studies used to contextualise measurement and technology findings	RQ3/RQ4	8	Elnadi et al. (2025); Chen and Zheng (2026); Tran et al. (2026)
Total			42	

Table 2: Classification by geographic focus

Primary geographic focus	Countries / coverage	No. of studies
West Africa	Nigeria, Ghana and the Gambia	9
Southern Africa	Zimbabwe and South Africa	7
East Africa	Uganda, Kenya, Ethiopia and Tanzania	9
Pan-SSA / Africa-wide	SSA or Africa-wide studies without a single-country focus	5
Non-SSA comparator	Global, Morocco, Vietnam, Peru, Pakistan, China, Malaysia and Saudi Arabia	12
Total		42

The country level evidence has been taken from nine SSA countries: Kenya, Ethiopia, South Africa, Uganda, Zimbabwe, Nigeria, Ghana, Gambia and Tanzania. There is equal representation from both West and East Africa, but no representation from Central Africa, or Southern Africa, except for Zimbabwe. Non-SSA studies are added as context for the measurement, digitalisation, integrated lean-agile approaches, rather than as a replacement for SSA evidence.

Table 3: Classification by methodology

Methodological approach	Description	No. of studies
Quantitative survey / statistical analysis	Regression, SEM/PLS-SEM, fsQCA or structured firm-level assessment	24
Qualitative / case-study evidence	Single- or multi-firm case studies and applied industrial investigations	10
Conceptual, theoretical or review studies	Definitions, reviews, scoping reviews and conceptual synthesis	6
Framework / model / measurement development	Formal agility, readiness or assessment frameworks and models	2
Total		42

Table 4: Classification by publication period

Period	No. of studies	Notes
Pre-2016 (baseline exceptions)	4	Gunasekaran (1998); Yusuf, Sarhadi and Gunasekaran (1999); Acquaaah and Amoako-Gyampah (2003); Routroy, Potdar and Shankar (2015)
2016–2020	2	Abdelilah et al. (2018); South African agile-practice evidence (Govender et al., 2018)
2021–2022	5	Early SSA flexibility, Industry 4.0, barrier and Ugandan studies
2023	5	African FMS, strategic-agility, Zimbabwean agility-strategy and Industry 4.0 studies
2024	1	South African flexibility and agility study
2025	8	Growth in SSA flexibility, Industry 4.0 and resilience evidence
2026	15	Largest annual cohort, including SSA studies and global comparators
Undated / incomplete metadata	2	Thesis-type records retained for relevance, publication metadata incomplete
Total	42	

Of the 42 studies, 23 (54.8%) were published in 2025–2026. This concentration shows rapid recent growth in research on manufacturing agility and flexibility in SSA, while the small number of older studies indicates that the empirical foundation of the field is still young.

5 RESULTS AND CRITICAL SYNTHESIS

5.1 Documented agility and flexibility strategies (RQ1)

The SSA evidence shows evidence of strategic agility, manufacturing flexibility, leagile production, workforce practice, supply-chain agility, lean adoption and operational responsiveness. In Uganda, studies have shown that agile and leagile capabilities are related to the performance of small and medium-sized factories (Nagaaba, 2021; Nagaaba, 2022).

Fofana, Nyarko and Takyi (2021) and Fofana et al. (2023) demonstrate that flexible manufacturing systems are not being embraced uniformly by companies in Ghana and The Gambia. Research in Nigeria looks at how the business environment affects organisational performance when managing uncertainty (Bassey, Uwa and Okurebia, 2023), the characteristics of the workforce and leadership (Uwadia, 2025), and the positive relationship between flexibility and enterprise performance (Okeke and Bello, 2026), while in Ghana, evidence shows that operations-management flexibility is positively related with procurement performance (Agbeka et al., 2025) and that collaboration with local

logistics providers for supply-chain agility is noteworthy (Mohammed, n.d.). The situation in East and Southern Africa is similar.

Research conducted in Kenya relates agility of market sensing to agility of supply-chain to production and business performance in listed manufacturers (Njenga and Mang'ana, 2026) and in the power-tool sector (Ali, n.d; Bosch Africa case study, n.d). In Tanzania, structural-equation modelling was used to identify the driver of lean adoption (Matindana, Sinkamba and Mgwatu, 2025) while value-stream mapping was used to improve efficiency at a rice mill (Matindana and Sinkamba, 2025). While strategic flexibility is linked with manufacturing flexibility and supply-chain agility, Gates and Mengyun (2024) argue that strategic flexibility is related to manufacturing flexibility and supply-chain agility, whereas agile practices is related to supply-chain resilience in food and beverage manufacturing, Govender et al. (2018) argue.

A survey of manufacturers in Zimbabwe revealed that organisational vision and efficiency was the primary enabler for agility, followed by very little contribution from consultants (Muhla et al., 2023); another study has explored the relationship between leadership and strategic flexibility in Zimbabwean SMEs ('Leadership and strategic flexibility', 2026). In that context, the suggested path towards agility involves customer-focused products, integrating design and production, and more effective channels for customer input along with inter-firm collaboration (Muhla et al., 2023). The strategy literature does not always account for an operational level of studies from the region. The use of DoE methods in injection moulding have reduced the set-up time by a large margin, with an L9 orthogonal array cutting the number of trials to optimise the process from 81 to 9 and also identifying settings that would be expected to reduce shrinkage from 1.55% to 0.64% (Mapindu et al., 2026a); similar Taguchi-grey relational analyses were used in CNC milling, in which conflicting optima were resolved, and in fused deposition modelling (Mapindu et al., 2026b and c, respectively); and multi-response optimisation of honing was performed, showing settings that both reduce surface roughness, another study was done on optimizing the weld parameters which determine the weld strength (Mapindu et al., 2026d) and save energy (Tayisepi et al., 2024).

Agile process qualification is faster and cheaper, reducing ramp-up after change or product introduction, the flexibility and mix/changeover that is often taken for granted and not measured by agile frameworks. A smart wheelchair with a dual mode of operation developed to allow the product to be maintained locally at 60–70% below that of commercial products is an example of the same at product level (Munotyani et al., 2026). As a whole, the literature suggests a positive link between adaptive capabilities and manufacturing outcomes and does not provide a clear-cut causal explanation. Agility or flexibility is sometimes used as a standalone predictor, or as part of a broader set of operational, supply-chain, technology or organisational models. This variation makes it difficult to compare effect sizes between studies.

5.2 Barriers to adoption (RQ2)

Unfortunately, high investment costs and the lack of skilled labor hinder sustainable adoption of Industry 4.0 in South Africa (Maisiri, Van Dyk & Coetzee 2021) and similar issues are reported among SSA SMEs (Peter, Pradhan & Mbohwa 2023). The lack of an Industry 4.0 strategy, the high cost of solutions and limited government support and fear of cyber-attack were the most cited barriers in Zimbabwe (Muhla et al., 2025a), agility adoption was impeded by limited managerial support, insufficient training and resistance to change, funding shortages and lack of enabling technologies like numerically controlled machines and rapid-prototyping equipment (Muhla et al., 2023).

Supply-chain risk, regulatory issues, and human-capital availability have been pointed out as key constraints to pharmaceutical manufacturing in Ethiopia (Mechal, Boche and Zambujal-Oliveira, 2025), and in SSA, manufacturing priorities have been long established to be influenced by human-capital availability (Acquaah and Amoako-Gyampah, 2003). Barriers vary in importance. Well-infrastructured companies focus on investment, skills and technology integration while less developed companies focus on stable power, efficient transport, connectivity and supplier access. Power reliability is a typical example, for instance in Zimbabwe, a thermal power plant with approximately 72% corrective maintenance had poor boiler reliability and forced outages (Senda et al., 2026), and forced outages of the thermal power plants directly translates into manufacturing downtimes.

The evidence, therefore, supports an interpretation of context-dependent barriers for SSA instead of a ranking of barriers. There's another layer of supply-chain resilience too. In Nigeria and Ghana, research on manufacturing firms and South Africa on food and beverage firms indicate that supplier relationships and logistics & visibility influence the ability of the firms to respond to disruption (Bassey, Uwa and Okurebia, 2023; Govender et al., 2018). Human factors are an under recognised barrier: unsafe practices, fatigue, cognitive overload and limited management commitment limit workforce adaptation capacity (Muhla et al., 2025b); and several studies suggest that management commitment is the common thread that makes the difference between the maintenance of training, technology and process changes (Muhla et al., 2023; Muhla et al., 2025a).

5.3 Measurement approaches (RQ3)

There is no uniformity in the literature concerning measurement. Routroy et al. (2015) develop a formal agility index, Potdar and Shankar (2015) explore enabling competence in a leagile manufacturing model and Ren (2026) introduces a multi-agent, retrieval-augmented AI framework to evaluate agility in digital manufacturing. Ali et al. (2026) conduct a structured analysis of enablers, barriers and drivers in the context of agile-manufacturing readiness of the developing-country SMEs. Typically, measurement in the SSA empirical literature is done through firm-level surveys or performance models instead of validated, region-specific agility tools.

Research thus employs a related but different construct, for instance, corporate agility, market-sensing agility, workforce agility, manufacturing flexibility, supply-chain agility and technology readiness. Results must be compared with caution and effect sizes from the numbers should not be considered as identical. There is also little connection of operational metrics to agility constructs. In the region, amounts typically reported for engineering studies could support objective agility metrics, such as the number of trials for a new process setting (Mapindu et al., 2026a), energy per operation (Tayisepi et al., 2023, 2024), mean time between maintenance (MTBM) and plant availability (Senda et al., 2026), and fault detection latency (Mashava et al., 2026). However, none of these is employed in the literature on measurement of agility.

5.4 Technology enablers (RQ4)

The focus of technology research is moving from willingness to use the technology to integration in digital manufacturing. Maisiri, Van Dyk and Coetzee (2021), Peter, Pradhan and Mbohwa (2023) and Muhla et al. (2025a) discuss the adoption environment while Achieng and Malatji (2022) examine digital transformation among SSA SMEs, Eziahi et al. (2026) explore innovation and transformation decisions in Nigerian manufacturing SMEs and Zhang, Telila and Jima (2026) present findings on the interaction of lean manufacturing, Industry 4.0 technologies, knowledge management and digital infrastructure within Ethiopian manufacturing. Additionally, there is a direct link between smart manufacturing and the agility of SMEs in an emerging economy, identified by the authors as 'The impact of smart manufacturing' (2026), as well as the application of lean practice and emerging technologies for resilient manufacturing in the rail sector in South Africa (Venkatasubbaiah et al., 2026).

Zimbabwean research indicates a pragmatic approach. Muhla et al. (2025a) note that numerous companies have sensors, PLCs and connectivity already in place, but haven't yet inter-connected them, and suggests a sequential implementation program with a focus on root cause analysis, project prioritisation, risk assessment, workforce evaluation, management buy-in and pilot projects. Both agent-based condition monitoring, which leverages existing PLC and OPC infrastructure (Mashava et al., 2026), and machine-learning maintenance decision support, trained on a plant's own historical data (Senda et al., 2026), translate data into faster, better-informed responses. Experimental designs can be employed to efficiently test the additive manufacturing which is not commonly used by Zimbabwean organizations (Muhla et al., 2025a) in university laboratories with low testing capacity (Mapindu et al., 2026c). Studies with comparators indicate a higher level of integration.

Tran et al. (2026) focus on the importance of human capital and cooperation in linking the industrial digitalisation with supply-chain resilience in Vietnam; Chen and Zheng (2026) warn about the potential for high automation to not mean innovation in smart factories; an exploratory case study in the Stellantis plant in Kenitra, Morocco (n.d. Effects of agile methods on production management), focuses on the impact of agile methods on production management; studies from Peru, Malaysia and Nigeria link lean tools and Industry 4.0 with efficiency, culture and technological resilience (Barzola Capcha et al., 2026; Ghazali et al., 2025; Amos-Fidelis et al., 2026). As a whole, it is evident that technology is not a source of agility itself but a facilitator in a broader socio-technical context.

5.5 Synthesis: what the evidence means as a whole

The 42 studies viewed collectively reveal a field that is growing empirical yet is fragmented. There are several links between agility, flexibility, lean practice, workforce capability, supply-chain responsiveness and digitalisation and all of them have an impact on the performance of manufacturing. However, agility, flexibility, lean practice, workforce capability, supply-chain responsiveness and digitalisation represent distinct and difficult-to-comprehend definitions, measurements and levels of analysis.

The evidence has been stronger for the value of adaptive capability than for any single path in the direction of improvement in performance. The most obvious finding is that a capability operating in an environment leads to its implementation. Whether a strategy which is effective in theory can be implemented in practice depends on the skills, investment capacity, infrastructure and the integration of the organisations involved in the supply chain. For highly digitalised systems, the human capital, knowledge, collaboration and organisational resources are still needed and essential (Chen and Zheng, 2026; Tran et al., 2026). A second finding is that SSA currently has operational building

blocks of agility including quick process qualification, data-driven maintenance and low-cost monitoring, but that these are nurtured within engineering research streams that do not connect with the strategic agility literature.

6 DISCUSSION

6.1 Implications for manufacturers

The evidence indicates a need to begin with the existing infrastructure for managers. Whole-sale technology replacement is more difficult than connecting existing sensors, PLCs and enterprise information, and implementing changes in a small scale then scaling up (Muhla et al., 2025a; Mashava et al., 2026). There is a need for changeovers to be streamlined to avoid trial and error (Tayisepi et al., 2023; Mapindu et al., 2026a, 2026b) and for structured experimentation to replace trial and error set-up, as this cuts down changeovers and results in documented process windows that can be used when changeovers of product or material occur. The shift from reactive to planned and data-informed maintenance is essential as equipment responsiveness is a prerequisite to equipment availability (Senda et al., 2026). Human factors, training and management commitment should not be considered compliance costs, but rather investments in agility, much like any other (Muhla et al., 2023; Muhla et al., 2025b; Tandi et al., 2025).

6.2 Implications for policy and education

The lack of government incentives and Industry 4.0 policy is reported as a limitation in Zimbabwe on several occasions (Muhla et al., 2025a) while the reliability of energy supplies is cited as a prerequisite for any form of response (Muyambo et al., 2025; Senda et al., 2026). The biggest obstacle throughout the corpus is skills. Learning factories that simulate real production environments for practical learning are suggested as a regional mechanism to overcome the theory–practice divide in engineering education in the region, as based on existing facilities in South Africa in a gradual process of preparation, capacity building, implementation, monitoring and sustainability (Ndiyamba et al., 2026). These platforms may also be used as a testbed to provide an opportunity for SMEs to experiment with agile production ideas without investing capital.

6.3 Limitations of the review

There are a few limitations to the review. This is a small body of 42 studies and a search--partly using Google Scholar, which is less reproducible than curated databases. Only sources in English language were taken into consideration, which may not be representative of Francophone and Lusophone Africa. There are records, primarily theses and regional journal articles, that have partial publication information. A formal risk-of-bias appraisal was not conducted, because the designs included are too heterogenous to be appraised using a single appraisal tool, so findings are reported descriptively. Finally, if the paper includes studies that answer multiple research questions, one classification per study makes them easier to comprehend.

6.4 Research Gaps and Future Research Agenda

A validated SSA agility instrument. No instrument for measuring agility has been validated in SSA; the literature uses different constructs and frameworks. Future work should develop and test a multi-level instrument that combines perceptual survey items with objective operational indicators such as changeover time, qualification effort, availability and fault-response latency.

Integrated treatment of infrastructure and capability. Cost, skills, infrastructure, digital connectivity, energy reliability and supply-chain reliability are usually examined separately, even though they interact during implementation. Configurational methods (for example fsQCA) and system-dynamics models could capture these interactions.

Operational and shop-floor evidence. Although the literature includes SMEs, listed manufacturers and large firms, it relies mostly on strategic and survey-based concepts. More evidence is needed on production systems, reconfiguration, scheduling and equipment-level flexibility, and on how process-optimisation and condition-monitoring capabilities translate into firm-level agility.

Socio-technical models. Digitalisation appears to work through human capital, knowledge, collaboration and organisational processes. Research should develop integrated socio-technical models that include human factors, ergonomics and safety culture alongside technology.

Longitudinal and intervention studies. Most evidence is cross-sectional, making it hard to determine how agility capabilities develop, persist and renew. Longitudinal panels, pilot-to-scale intervention studies and learning-factory-based experiments would address this.

7 CONCLUSIONS

This systematic review compiles 42 studies on manufacturing agility and flexibility specific to Sub-Saharan Africa, including some global and developing-economy studies. There is a link between agility and flexibility, and responsible and performing SSA manufacturers, although the mechanisms and measures differ: Common constraints are cost, skills, infrastructure, power reliability and condition of the power supply chain, and management commitment is also a key factor in sustaining change. Industry 4.0 and the digital technologies are facilitators which are dependent on the organizational and human capabilities.

The final corpus is 42 studies, which is consistent with the PRISMA flow, and the taxonomy. The evidence base is rapidly growing with 23 of the 42 studies published in 2025–2026. The key research challenge now, however, is not simply to reaffirm the importance of agility but to quantify, introduce and improve agility-aware methods in a context-appropriate manner. A practical path to this goal is achieved by integrating the strategic agility literature with the operational evidence that has emerged in the region on process optimisation, data driven maintenance and low cost monitoring and with mechanisms for capability building like learning factories.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Disclosure of conflict of interest

The authors declare no conflict of interest.

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