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Factors shaping Quality 5.0 adoption in South Africa: Exploratory Factor Analysis

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Abstract

In today's disruptive business environment, organizations must constantly seek new methods to meet client needs, including offering environmentally friendly products and services. Studies show that Industry 5.0 practices, particularly Quality 5.0, have the potential to transform processes and ensure sustainable and resilient quality practices while meeting customer demands. However, the implementation of Quality 5.0 is unfamiliar, and its adoption trajectory is setting specific, with businesses in advanced economies responding better than those in developing nations like South Africa. This study uses an online survey of 50 people selected using snowball sampling to discover factors that shape Quality 5.0 readiness in developing economies based on their distinct economic, infrastructure, skills, and socioeconomic characteristics. The study used EFA to identify elements relating to sustain-ability, human-centeredness, responsible technology adoption, and resilience that, if ignored, could threaten the success and ethical responsibility of Quality 5.0. The study recommends ethical Quality and environmentally responsible 5.0 adoption following the empirical framework developed in this study to ensure that value is extracted from Industry 5.0 initiatives.

Keywords
Quality 5.0, Human-centricity, Sustainable manufacturing, resilience, South African manufacturing

1. Introduction
Globally, the manufacturing landscape is projected to shift as nations transition to Industry 5.0 to address Industry 4.0 shortcomings relating to sustainability, resilience, and human centricity (Martín-Gómez, Agote-Garrido and Lama-Ruiz, 2024; Mentzas *et al.*, 2024; Narkhede *et al.*, 2024). These developments coupled with the fluidity of customers means organizations must constantly seek new methods to meet client needs, including offering green and socially responsible products and services (Martín-Gómez, Agote-Garrido and Lama-Ruiz, 2024; Müller and Van Dyk, 2024). In this period, Quality 5.0 emerged as a new frontier in quality management, attempting to integrate modern technologies such as artificial intelligence, big data and analytics, robotics, and cyber-physical systems with human values, environmental responsibility, and organizational resilience to transform traditional quality management practices (Arsovski, 2019; Arıcı and Kitapci, 2021; Frick and Grudowski, 2023; Martín-Gómez, Agote-Garrido and Lama-Ruiz, 2024). Quality 5.0, like any other industrial revolution, is anticipated to offer novel effects, yet its trajectory is inconsistent in various settings. This is particularly pronounced in developing economies including South Africa, where factors such as limited infrastructure, skill mismatches, government structures and support, and overall readiness create distinct obstacles and opportunities (Mhlongo and Nyembwe, 2024a).

Developed economies typically require few sacrifices and have the backing and digital maturity to shift to newer revolutions, as opposed to their developing counterparts, who are likely still one revolution behind (Maganga and

Taifa, 2022b, 2022a; Mhlongo and Nyembwe, 2024a). However, Quality 5.0 and Industry 5.0 programs go beyond technological breakthroughs to ensure growth for all through inclusivity. This demonstrates that developing regions have unique socioeconomic dynamics and capacities that can influence the development of Quality 5.0 in unexpected ways. Understanding these shaping factors is critical for developing Quality 5.0 strategies that are not only technically sound, but also contextually relevant and sustainable. The purpose of this study is to investigate the key factors shaping the development and adoption of Quality 5.0 in South African manufacturing organizations. The research employs an Exploratory Factor Analysis (EFA) approach to discover latent items that influence organisational readiness to implementation. This study provides empirical findings that can be used to inform policy, strategy, and academic discussions about digital transformation and quality evolution in developing countries. This study contributes to theory and practice by articulating a locally relevant knowledge of what enables a successful transition to Quality 5.0, as well as how such adoption might promote South Africa's long-term industrial growth and competitiveness aligned with United Nations's sustainable development goals.

1.1 Objectives

The main objectives of this study are as follows:

- To investigate the factors that shape successful and sustainable adoption of Quality 5.0 in South African organizations
- To develop an empirical framework for Quality 5.0 adoption in South Africa

2. Theoretical Background

2.1. Industry 5.0

According to Pant et al. (2025), shortcomings from Industry 4.0 were its failure to meet the urgent need for customization and achieving growth beyond employment and profits which would ensure a sustainable future for humanity. The strong point of Industry 5.0 is that organisations that transition to Industry 5.0 practices believe that societal goals can be achieved alongside growth and profits (Fukuda, 2020; Adel, 2022; Ghobakhloo *et al.*, 2024). Industry 5.0 is bringing about a paradigm shift in the manufacturing sector by making production processes more sustainable, individualized, and efficient. The integration of cutting-edge technologies like artificial intelligence (AI), robotics, and the Internet of Things (IoT) defines this evolution, enabling machines to assist human creativity and decision-making instead of merely automating tasks (Fukuda, 2020; Maljugić *et al.*, 2024; Pant *et al.*, 2025). In order to create an agile production line that satisfies customized client requests while cutting waste and increasing resource efficiency, the primary goal is to improve human-machine collaboration (Fukuda, 2020; Fanoro et al., 2021; Pant et al., 2025). As a result, this synergy creates a more responsible and responsive manufacturing environment that meets the growing need for sustainability.

2.2. Quality 5.0

To address production flaws and challenges, and ensure continuous improvement of processes in any revolution, a quality management regime is needed (Arsovski, 2019; Fanoro, Božanić and Sinha, 2021; Frick and Grudowski, 2023; Fiałkowska-Filipek and Dobrowolska, 2024). Quality regimes have always been shaped by fluid customer requirements and the same is true for Quality 5.0 which is shaped by customer green and socially responsible products expectations (Revolutionized, 2024). The fifth evolution of quality management practices, also known as Quality 5.0, reflects the transformative impact of integrating modern and green technologies into quality concepts to improve industrial processes(Arsovski, 2019; Fiałkowska-Filipek and Dobrowolska, 2024). Above offering product/service quality, this evolution, unlike previous quality control measures, emphasizes a holistic view encompassing customer satisfaction, employee engagement, sustainability, forward planning and social responsibility (Bajic *et al.*, 2023).
Quality 5.0 features the use of key industrial technologies to monitor and control various devices such as sensors, cameras and others and gather, analyse and make data driven decisions in real time (Fiałkowska-Filipek and Dobrowolska, 2024).

Another key feature in Quality 5.0 is cobots, the collaboration between machines and humans. Cobots explains a harmonious process encompassing engaging and empowering humans with the tools and knowledge needed to perform critical thinking and analytics on quality data and make sound decisions while robots streamline and optimize processes (Fanoro, Božanić and Sinha, 2021; Ghobakhloo *et al.*, 2024). With these features, Quality 5.0 allows for the identification and prediction of quality defects and influence process remedial actions. Quality 5.0 is also forecasted to solve the mismatch between manufacturing needs and societal needs for sustainability and human well-being through its and its innovative vision (Pant *et al.*, 2025). According to Kovari (2024), companies that transition to Industry 5.0 won't only achieve their sustainable development goals but will also gain competitive advantage against their rivals.

2.3. South African Setting

Over the last few decades, the South African manufacturing sector has faced persistent product recalls due to poor quality, as well as other challenges such as reduced profits and sectorial outputs owing to a variety of factors such as global competition and socioeconomic challenges such as energy insecurity, insufficient government and regulatory support, infrastructure limitations, and skill mismatches (Moshikaro, 2020; Mhlongo and Nyembwe, 2023; Mangaroo-Pillay, 2024; Uzenzele, 2024). Maharaj (2022) found that adopting digital technologies and reshaping production processes has potential to enhance efficiency, reduce costs and improve product quality thereby redefining the sector to be great again. Other researchers corroborated this and suggested the use of modern technologies to improve manufacturing processes, and subsequently improve quality (Siphoro *et al.*, 2020; Mhlongo and Nyembwe, 2023). South Africans have also faced various challenges including job losses due to factors like complete automation, global competition and economic instability (Zalk, 2014; NAACAM, 2019; Moshikaro, 2020).

As a solution to these challenges, the president of South Africa, Cyril Ramaphosa presented the national strategy which underscores the goal of fully tapping into responsible technological innovation by 2030 (Maisiri and van Dyk, 2019; Shivdasani, 2019). He urged that South Africa could use advanced technologies to address persistent socio-economic issues such as inequality, unemployment, and poverty in the nation. This also supports the goal set out by the United Nations to fully adopt resilient infrastructure, promote sustainable industrialization and foster innovation to realize global economic growth, particularly in developing nations by 2030 (Sampedro, 2021; Guterres, 2023). This makes Quality 5.0 adoption in this country a strategic necessity more than just a technological advancement. Understanding the drivers and enablers of Quality 5.0 becomes critical. Despite increased academic interest in Quality 5.0 around the world, the discipline is still in its infancy, and more research on the contextual variables shaping its adoption in emerging economies such as South Africa is required.

2.4. Shaping Factors

Studies from seasoned quality management authors found that in order for organisations to adopt any new quality regimes they have to ensure several factors such as: (i) top management support , (ii) reliable connectivity infrastructure, (iii) leadership, (iv) trainings and rewards, (v) aligned vision and strategy , (vi) customer readiness, (vii) knowledge and awareness, (viii) supplier centeredness, (ix) quality culture, (x) financial set-up, (xi) modern technology, (xii) skills and capabilities, (xiii) collaboration and (xiv) governance compliance (Maisiri and van Dyk, 2019; Nafchi and Mohelská, 2020; Sony and Naik, 2020; Sony et al., 2021; Mhlongo and Nyembwe, 2024a). In the Fifth Industrial Revolution, all these constructs must follow the 3 core features: sustainability, resilience and human-centredness. However, over and above these generic factors, firms in South Africa face several factors that may hamper adoption to advanced developments which may be peculiar to it, and other developing nations, which generic migration frameworks may not address (Serumaga-Zake and van der Poll, 2021). Some of the challenges may be a result of inequality, unemployment rates and socio-economic factors. For example, Bhorat et al. (2017) claim that the legacy of colonization is still evident in pervasive inequality, which still raises the standard of living for a small number of people while excluding the rest. In South Africa, settler colonial policies that forced people of colour into rural areas, limited their employment options to low-wage jobs, and provided them with inadequate education exacerbated the systemic injustices of colonialism.

Considering this legacy, which has not been completely overcome, any attempts to transition to a different revolution could increase unemployment, poverty, and inequality levels, if the planning process does not account for inclusive growth (Bhorat and Rooney, 2017; Serumaga-Zake and van der Poll, 2021). Moreover, according to Serumaga-Zake et al. (2021), businesses in developed cities with more dependable and technologically advanced infrastructure are more likely to make the transition to Industry 4.0 and beyond than their counterparts in rural areas because of colonization and the inequity that goes along with it. Modern technologies and innovations are easier to integrate into a modern infrastructure. Therefore, it may be said that inequality affects businesses as well as individuals, and therefore the plan to upgrade should account for this. Rural residents are also forced to take low- and semi-skilled occupations as a result of the insufficient education system in rural areas brought on by urban-rural inequality (Bhorat and Rooney, 2017; Alexander, 2022). Furthermore, high earners who reside in cities with more developed educational systems are more likely to continue upskilling, which makes them desirable candidates for new age job opportunities, according to Maisiri et al (2021). As robots and artificial intelligence replace manual labour, which is typically provided by low-skilled individuals, those from rural areas who have lower skills and are frequently from disadvantaged backgrounds are at a significantly higher risk of losing their jobs.

This will increase the unemployment gap that decolonization efforts are intended to close (Scott, 2018; Alexander, 2022). The pursuit of modern technology initiatives in South Africa is also severely hampered by inequality, which affects labour unions, disrupts labour markets, and jeopardizes low-skilled jobs (Serumaga-Zake and van der Poll, 2021). According to a Maharaj (2022) , more than 15% of manufacturing companies acknowledged that labour unions opposed the adoption of modern technology because they were worried about job losses. Maisiri et al. (Maisiri and Van Dyk, 2021a) agreed, pointing out that most labour unions in South African enterprises are seriously impeding the successful adoption of new technology since they are more concerned with job losses than with the advantages of these technologies for current employees.

Socioeconomic issues, which mostly affect emerging nations like South Africa, will lead to poverty and inequality in addition to more unemployment (Maisiri and Van Dyk, 2021a; Maharaj, 2022). This implies that, in contrast to their counterparts in developed countries, South Africa should prioritize inclusive growth in addition to economic competitiveness when implementing Quality 5.0. When implementing Quality 5.0, the entire industry and economy should be considered rather than just individual firms. Quality 5.0 is a value inclusive programme; however, it's true value may only be realised properly if all the factors that shape its adoption are prepared for. This emphasizes the need for this study, to empirically identify a framework of shaping factors which determines the planning organizations have to embark on before they can successfully adopt Quality 5.0.

3. Methodology

The research explores the factors shaping successful and sustainable Quality 5.0 adoption in South African organisations using an online survey. The study targets stakeholders and experts in the manufacturing and production sector who carry out research or quality management tasks, as the unit of analysis. The participants are identified through a snowballing method, starting with 15 personnels already known to the researchers. This sampling method is preferred as it has the potential to reach more seasoned in the field individuals and enrich the study as it is based on referrals (Ohiomah and Sukdeo, 2022). This study received a total of 50 responses. The research methodology was divided into four distinct steps: The first step encompasses formulating the research problem, the second step entails an intense review of available literature from journal articles, conference papers, reports and books. The intense review of literature culminated in a theoretical framework which was used to develop the online survey questionnaire. The third step entails designing the questionnaire and collecting data from the participants using electronic survey platforms. The fourth step involved analyzing the data. This study adopted quantitative analysis, where reliability assessments, factor analysis and construct validity were performed.

3.1. Questionnaire

According to Ohiomah and Sukdeo (2022), surveys are a preferred method to collect data as they are cost effective, cover a wide reach and effectively measure various variables. Makhanya et al. (2019) suggested that latent variables that cannot be measured using standard measuring tools are ideally measured using a survey. The paradigm of factors shaping Quality 5.0 adoption cannot be measured using the standard measuring tools like rulers, temperature sensors and other similar tools. It is hidden in people's experience, behavior, and knowledge within their organisations, and therefore a survey is the best instrument to use. Studies by Mhlongo and Nyembwe (2024a) and Maganga and Taifa (2022b) used survey methods to uncover and provide insights on technological adoptions in the manufacturing sector. The instrument was developed using knowledge acquired from a comprehensive literature review and was split into two parts. The initial part is for demographics and general information, which attempts to understand the respondent's level and character. The second part examines all the factors that shape effective Quality 5.0 implementation and is scored using a 5-point Likert scale, with 1 indicating "strongly disagree" and 5 indicating "strongly agree."

4. Results and Discussion

The reliability of the questionnaire tested for the Cronbach alpha test, and an alpha value of 0.92 was derived, implying that the instrument used was highly reliable as this alpha value was higher than the 0.7 cut-off criteria (Mhlongo and Nel, 2021; Mhlongo and Nyembwe, 2024a). Given that 34 shaping factors were evaluated, it was possible that some of the factors would have comparable underlying impacts. To narrow down the enormous groups of factors into a smaller number of underlying grouped factors, an exploratory factor analysis (EFA) was carried out. This approach involves finding items with low (MSA) <0.6 and those causing double loading (Ohiomah and Sukdeo, 2022). The study eliminated 6 items that caused cross loading.

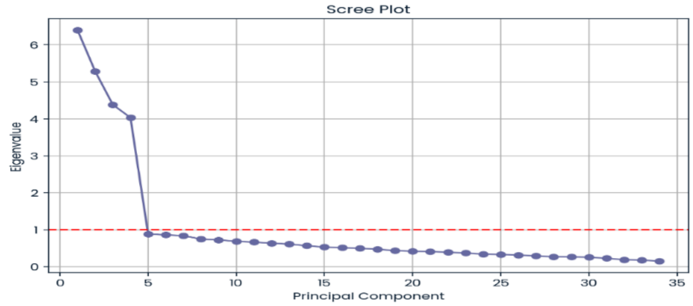

Figure 1 Scree plot of factors with Eigenvalue ≥ 1

To verify the suitability of this dataset for factor analysis, this study revealed a KMO index of 0.785 and the Bartlett's Test of Sphericity (Chi-Square = 1614,516, df = 295.3, p-value < 0.05) which indicates that there was no sampling problem in this study. EFA was carried out with ProMax as the rotation method and principal component analysis as the extraction method. 4 (four) extractions with an eigenvalue of 1 or above were found by PCA (as seen on Figure 1), and when combined, they account for 67%, which is more than the 50% requirement for a satisfactory extraction as noted by Ohiomah and Sukdeo (2022).

4.1. Demographics

Table 1 shows the demographics of the respondents. The majority (48%) of respondents were between the ages of 31 and 40, with 42% having 11 to 15 years of experience in their respective fields. 56% of respondents held a postgraduate degree, and 30% were engineers. These findings reflect the qualities of the respondents.

Table 1. Demographics

Demographic	**N**	**Frequency (%)**	**Cumulative (%)**
Age			
20 - 30 years	5	10%	10%
31 – 40 years	24	48%	58%
41 – 50 years	12	24%	82%
> 50 years	9	18%	100%
Years of Experience			
0 – 5 years	11	22%	22%
6 – 10 years	15	30%	52%
11 – 15 years	21	42%	94%
16 – 20 years	1	2%	96%
> 20 years	2	4%	100%
Level of Education			
Matric	0	0%	0%
National Diploma	10	20%	20%
Bachelor's Degree (s)	12	24%	44%
Postgraduate Degree (s)	28	56%	100%
Current Job			
Technician	5	10%	10%
Engineer	15	30%	40%
Manager	11	22%	62%
Supervisor	9	18%	80%
Specialist	10	20%	100%

4.2. Exploratory Factor Analysis Results

Table 2 presents four (4) factors that shape Quality 5.0. The first principal component accounts for the most significant percentage and has the highest number of variables loading. The variables loading on this component are :The quality strategy aligns with sustainable development and environmental goals, We comply with environmental and sustainability-related regulations in our quality practices, The organization allocates sufficient budget for sustainable quality initiatives and technologies, We design our products and processes with the principles of the circular economy in mind, We actively invest in and adopt green technologies to reduce our environmental impact, Our organization supports rural development initiatives that prepare underserved areas for Quality 5.0, Our organization contributes to inclusive employment in marginalized or rural communities, Our customers are willing to support ethically and technologically advanced quality initiatives, We collaborate with external partners to ensure inclusive and socially responsible quality practices, We contribute to infrastructure development in underserved regions to support inclusive quality transformation and because it explains the preparedness to adhere to sustainability goals in the 5th Industrial Revolution it is named "Sustainability Factors".

A high score on these parameters indicates that a business is ready to address Quality 4.0 inadequacies in this new industrial revolution while maintaining quality and process optimization. Using sustainability factors to shape Quality 5.0 initiatives in an organization supports global literature which found that in the 5th Industrial Revolution, quality management systems should look beyond automated processes and real-time monitoring and/or profits, but should seek to achieve all of that in an environmentally responsible and green manner, as seen in studies by Arsovski (2019) and Frick and Grudowski (2023), who conceptualized Quality 5.0 as a paradigm that seeks to achieve sustainable quality management practices. This factor is also consistent with the national government's purpose of investing in and encouraging the adoption of modern technology to enhance processes and relieve the triple threat (poverty, unemployment, and inequality) (Maharaj, 2022; Mhlongo and Nyembwe, 2023; Mhlongo and Nyembwe, 2024a). Although the findings of this study are in line with the literature, other studies have identified gaps in implementation. For example, sustainability approaches are frequently resource-intensive, posing a challenge for businesses in developing countries, where economic restrictions and inadequate infrastructure limit green investment (Liu et al., 2024; Rame et al., 2024; Maisiri and van Dyk, 2021b). This implies that, while sustainability is a widely emphasized pillar of Quality 5.0, its practical implementation may vary under various settings.

Table 2. Quality 5.0 Empirical Framework

	Factors				**Communalities**
	1	**2**	**3**	**4**	**Extractions**
Sustainability Factors					
The quality strategy aligns with sustainable development and environmental goals	0,86				0.89
We comply with environmental and sustainability-related regulations in our quality practices	0,84				0.9
The organization allocates sufficient budget for sustainable quality initiatives and technologies	0,81				0.9
We design our products and processes with the principles of the circular economy in mind	0,81				0.87
We actively invest in and adopt green technologies to reduce our environmental impact	0,79				0.86
Our organization supports rural development initiatives that prepare underserved areas for Quality 5.0	0,78				0.84
Our organization contributes to inclusive employment in marginalized or rural communities	0,77				0.84
Our customers are willing to support ethically and technologically advanced quality initiatives	0,76				0.89
We collaborate with external partners to ensure inclusive and socially responsible quality practices	0,72				0.76
We contribute to infrastructure development in underserved regions to support inclusive quality transformation	0,71				0.94
Human-Centric Factors					

Employee training and incentives programs are encouraged		0,85			0.88
Top management provides strong support for initiatives that prioritize people in quality transformation		0,84			0.82
Skills development and training are aligned with future-oriented quality and technology needs		0,8			0.87
Hiring practices promote inclusive employment and uplift historically disadvantaged groups		0,7			0.83
We collaborate with education providers to reengineer curricula aligned with Quality 5.0 needs		0,65			0.87
We ensure fair and responsible use of AI in all processes, including recruitment and production		0,64			0.82
Employees have the knowledge and awareness of digital tools and how they are used to improve product and process quality		0,61			0.74
We actively involve employees, labor unions and local communities in Quality 5.0 transformation to gain their support		0,60			0.82
Responsible Technology Adoption Factors					
We have adequately adopted smart technology and quality tools			0,82		0.82
We have the technical capability to manage and analyze quality-related data effectively			0,81		0.8
We have reliable digital infrastructure to support Quality 5.0 technologies			0,7		0.81
We engage suppliers who align with our ethical standards and quality expectations			0,69		0.78
We reserve technology for dangerous and repetitive tasks			0,64		0.82
Resilience Factors					
We work closely with other organizations to build collective capacity and resilience in quality systems				0,77	0.88
The government supports our initiatives and continuously provides us with resources and a healthy operating environment				0,75	0.9
We receive support from the government and the local policies and regulations support our Quality 5.0 initiatives				0,73	0.91
Our leadership promotes agility and responsiveness to change in quality management				0,71	0.72
Our financial planning enables us to invest in long-term quality improvements and risk management				0,7	0.82
Kaiser–Meyer–Olkin Measure		0,785			
Bartlett's Test of Sphericity	X2	1614, 516			
	Df	295,3			
	sig	0,000			
Cronbach Alpha		0,92			

The second principal component is loaded with: Employee training and incentives programme are encouraged, Top management provides strong support for initiatives that prioritize people in quality transformation, Skills development and training are aligned with future-oriented quality and technology needs, Hiring practices promote inclusive employment and uplift historically disadvantaged groups, We collaborate with education providers to reengineer curricula aligned with Quality 5.0 needs, We ensure fair and responsible use of AI in all processes, including recruitment and production, Employees have the knowledge and awareness of digital tools and how they are used to improve product and process quality, We actively involve employees, labour unions and local communities in Quality 5.0 transformation to gain their support and these construct relate to ensuring human-centricity in the 5th Industrial

Revolution and is thus named “Human-Centric Factors”. This component includes factors like curriculum alignment, inclusive hiring, ethical AI use, and staff training that show an investment in people.

In the current era, companies are concerned with bringing humans back into the process to collaborate with machines rather than being entirely replaced by them; this phenomenon is known as "cobots," and this component will assist organizations in shaping and complying with Industry 5.0 criteria (Frick and Grudowski, 2023; Keenavinna and Wickramarachchi, 2024; Kovari, 2024; Narkhede *et al.*, 2024). Identifying this factor on these results is consistent with literature by Mentzas et al. (2024), Rane et al. (2024) and Adel (2022) who discovered that in this era, organisations should not only streamline processes and ensure quality but also bring humans back and ensure that they are used for all critical thinking and decision-making roles. This element emphasizes how important human capital development is to making Quality 5.0 possible. This factor is consistent with the President’s report which called for socially just and human-centred technological deployment (Mhlongo and Nyembwe, 2024a; 2024b). Furthermore, the emphasis on inclusive employment also mirrors South Africa's Employment Equity Act, suggesting compliance and ethical alignment in recruitment practices (Maisiri and Van Dyk, 2021a, 2021b).

Contrary to the consistent nature of results with global literature, other studies found that while AI and data-driven decision-making became central in the on-going industrial era, ethical concerns emerged, particularly in hiring, surveillance, and bias, for instance the Amazon’s AI-driven hiring system discriminated against women, reflecting a lack of oversight in AI ethics especially in contexts with historical skewed data (Drage and Mackereth, 2022; Mujtaba and Mahapatra, 2024; Revolutionized, 2024). However, this recent study and the other corroborating studies suggest that these are the challenges that Industry 5.0 practices aim to address. Moreover, developed economies may be better positioned to invest in upskilling, while developing nations face persistent education and skills mismatches (Sony, M. and Naik, 2020; Maisiri and van Dyk, 2021b). These tensions highlight the uneven global readiness for human-centric Quality 5.0 adoption.

The third principal extracted was loaded with the following variables :We have adequately adopted smart technology and quality tools, We have the technical capability to manage and analyse quality-related data effectively, We have reliable digital infrastructure to support Quality 5.0 technologies, We engage suppliers who align with our ethical standards and quality expectations, We reserve technology for dangerous and repetitive tasks. These variables define how technology will be used to bring value and not disrupt lives negatively in the 5th Industrial Revolution and is thus named “Responsible technology adoption factors”. Industry 5.0 encourages the use of emerging technologies to expedite operations, real-time monitoring, and predictive analytics, yet all of this must be done in an ethical and socially acceptable manner. This factor categorizes aspects related to the adoption and ethical use of modern technologies. The emphasis is not only on acquiring smart tools, but also on their proper and safe application, such as using technology for dangerous and repetitive tasks or in collaboration with humans and not to replace them, which is consistent with global literature (Leng *et al.*, 2022; Frick and Grudowski, 2023; Narkhede *et al.*, 2024). This is also consistent with local research, which indicates that successful digital transformation in South African manufacturing requires responsible and inclusive technology governance, particularly in environments where a digital divide and poor trust in automation persist (Maisiri and Van Dyk, 2021b; Maisiri, van Dyk and Coeztee, 2021; Mhlongo and Nyembwe, 2023; Mhlongo and Nyembwe, 2024b). Although these results are consistent with previous research calling for responsible implementation of modern technology (Leng *et al.*, 2022; Frick and Grudowski, 2023; Narkhede *et al.*, 2024), conflicts arise. In some cases, businesses may prioritise automation for cost savings, thereby damaging human-centeredness. Furthermore, developing nations like as South Africa suffer infrastructural barriers (for example, unstable connectivity and power outages) (Moshikaro, 2020; Mhlongo and Nyembwe, 2024; Mangaroo-Pillay, 2024; Uzenzele, 2024), which may impede sustainable adoption despite organizational willingness.

The fourth and last principal component extracted was loaded with the following variables: We work closely with other organizations to build collective capacity and resilience in quality systems, The government supports our initiatives and continuously provides us with resources and a healthy operating environment, We receive support from the government and the local policies and regulations support our Quality 5.0 initiatives, Our leadership promotes agility and responsiveness to change in quality management, Our financial planning enables us to invest in long-term quality improvements and risk management. These variables define how organizations are prepared to continue operating amidst adverse events and changes, hence this component is named “Resilience Factors”. This component emphasizes strategic readiness, ethical governance, agility, and regulatory support, which are all critical for surviving shocks and adjusting to future disruptions. Identifying this factor corroborates literature which emphasizes Quality 5.0’s potential ability to proceed with operations amid disruptions (Martín-Gómez, Agote-Garrido and Lama-Ruiz, 2024; Narkhede *et al.*, 2024). According to Revolutionized (2024) and Hickey (2023b), this would be beneficial when worldwide interruptions like COVID-19 occur, allowing industries to continue operating.

While resilience is widely recognized as essential, disagreements remain regarding the extent to which government support can be relied upon. Some studies emphasize policy-driven transformation (Uzenzele, 2020; Alexander, 2024), whereas others caution that government initiatives in developing economies may be slow or inconsistently enforced (Maharaj, 2023; Mhlongo and Nyembwe, 2024). Thus, resilience in Quality 5.0 may be more dependent on internal leadership agility and collaborative networks than on external policy frameworks in such contexts. These factors and this empirical framework define Quality 5.0 adoption, which involves the use of advanced technologies to improve and optimize production processes, ensure quality assurance, and add value by augmenting human intelligence and capabilities. Technology is used to provide value rather than completely automate tasks, leaving humans isolated and disrupted.

4.3. Quality 5.0 readiness Framework

The EFA found four unique but interconnected features influencing Quality 5.0 adoption: sustainability, human-centeredness, responsible technology adoption, and resilience.   When these factors are viewed together, as shown in Figure 2, they provide a framework for preparedness that organizations, particularly those in developing nations, can use to guide their transition to ethical, sustainable, and socially conscious quality management practices.   This four-factor framework has the potential to serve as a Quality 5.0 adoption readiness index.

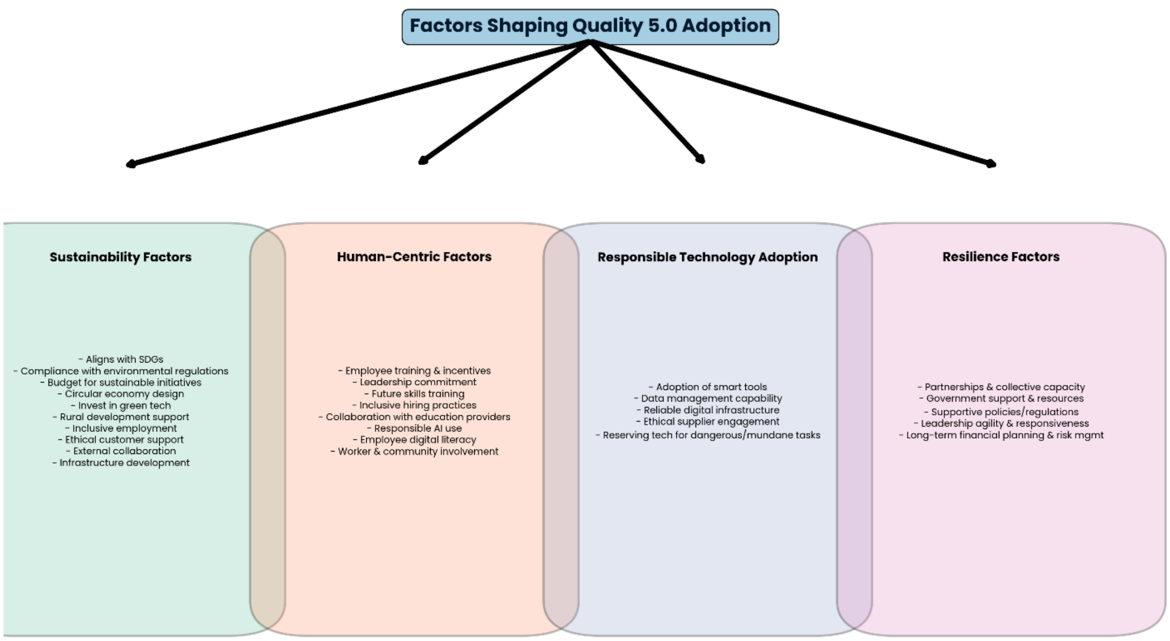

Figure 2. Framework for Quality 5.0 readiness

Benchmarking organizations against these criteria help policymakers and practitioners identify skill gaps and prioritize reforms.   Organizations, for instance, might establish ethical technology standards, universities could work with industry to develop skills, and governments could create incentives for sustainable investment.

5. Conclusion and Recommendations

This study identified four interconnected factors influencing Quality 5.0 adoption in the South African manufacturing sector: sustainability, human-centricity, responsible technology adoption, and resilience. Together, these factors provide both a theoretical contribution, by structuring the emerging Quality 5.0 paradigm, and an applied contribution, by offering a readiness tool that industry leaders and policymakers can adapt to assess preparedness. The results point to priority actions from a practical perspective. To successfully integrate cutting-edge technologies, manufacturers should prioritize human-centricity at the outset. This includes funding inclusive hiring, ethical AI practices, and employee training. Resilience enablers, such as bolstering infrastructure reliability, encouraging cooperative networks, and guaranteeing supportive regulatory frameworks, should be given top priority by policymakers. Although sustainability is still a vital long-term objective, attaining it in settings with limited resources might call for specific incentives, subsidies, or public-private partnerships to prevent putting an undue burden on businesses.

The framework's relevance extends beyond South Africa's industrial reality, addressing difficulties in other developing economies. As a result, it has the potential to serve as a general readiness indicator for the implementation of Quality 5.0 in developing economies. However, validation using bigger, cross-country datasets is required to ensure its stability and transferability. This study provides a framework that is philosophically and practically applicable by linking local industrial conditions to global Quality 5.0 topics. The findings may assist manufacturers' strategic planning, guide policy development, and motivate more comparative research into how Quality 5.0 might support resilient, inclusive, and sustainable industrial transformation.

To guarantee that technologies add value and are socially and environmentally responsible, the study recommends organizations to pursue long-term success by including environmental and social responsibilities, as well as ethical practices, into their quality management frameworks, and aligning their long-term quality strategies with local and global standards and requirements. Organizations must ensure that technologies complement rather than replace human workers, especially in vulnerable sectors. Furthermore, to overcome the gap between skills required and education provided in local education, industry and education institutions should collaborate to connect curricula with future-oriented quality and digital capabilities. Lastly, national and regional authorities should provide structures and incentives to encourage quality. 5.0 Adoption. Government incentives and support, such as the Green Fund, may help to speed this convergence.

6. Limitations and Future Research

This study has some limitations that should be noted. First, while the sampling adequacy was confirmed (KMO = 0.785, Bartlett's Test $p < 0.001$), larger samples are recommended in future studies to confirm factor stability and generalizability. Second, the study used self-reported survey data, which may have been influenced by respondent bias. Third, while the exploratory and confirmatory factor analyses provided valuable insights, the models were based on cross-sectional data and so could not represent dynamic changes in organizational environments over time. To improve generalizability, future research should replicate this study with bigger and more diverse samples drawn from different sectors. Longitudinal studies would also be useful for observing causal links and the progress of Quality 5.0 adoption over time. Furthermore, incorporating qualitative methodologies or case studies may provide deeper contextual insights that supplement statistical findings.

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