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An SLR on the Implementation of Industry 4.0 Within the South African Automotive Industry

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Abstract

The South African automotive industry is considered one of the most technologically advanced manufacturing sectors within the country. However, the extent to which Industry 4.0 and Lean 4.0 principles have been implemented remains uncertain. This study presents a systematic literature review aimed at determining the current level of Industry 4.0 implementation within the South African automotive industry and identifying the primary benefits, barriers and drivers influencing its adoption. A structured review methodology was applied using Scopus, Web of Science and IEEE Xplore databases. An initial 36 articles were identified and reduced to 18 relevant peer-reviewed studies following defined inclusion, exclusion and quality assessment criteria. The literature was analysed to classify the degree of implementation and extract recurring themes. The findings indicate a medium level of implementation, characterised by emerging and partial adoption with isolated advanced applications rather than full integration. Productivity, profitability and quality improvement are the most cited benefits. Key barriers include skills gaps, high investment costs and worker resistance. Adoption is primarily driven by competitive pressure and global value chain alignment. Overall, implementation is incremental and business-driven rather than strategically integrated.

Keywords
South African automotive industry, Industry 4.0, Lean, 4IR, Fourth Industrial Revolution

1. Introduction
The South African automotive industry is widely regarded as one of the most technologically advanced and economically significant manufacturing sectors within the country (Alexander, 2021). As a major contributor to exports, employment and industrial development (Alexander, 2021), its continued competitiveness is closely tied to its ability to adopt and integrate emerging manufacturing paradigms (Macpherson *et al*., 2023). Globally, Industry 4.0 and the Fourth Industrial Revolution (4IR) have reshaped manufacturing through the integration of cyber-physical systems, data analytics, artificial intelligence, automation and interconnected production environments (Sanders *et al*., 2016). In parallel, Lean manufacturing has continued to evolve, giving rise to the concept of Lean 4.0, where traditional waste reduction principles are enhanced through digital technologies (Naciri *et al.*, 2022).

While Industry 4.0 adoption has been extensively discussed in international literature, its implementation within developing economies remains uneven and context dependent (Hammad *et al.*, 2025). In the South African context, the automotive sector is often described as a leader in technological advancement relative to other domestic industries (Macpherson and Werner, 2025). However, despite growing discussion of digitalisation, automation and smart manufacturing within the sector, the actual extent of Industry 4.0 implementation is unclear. Existing studies provide valuable but fragmented insights, frequently focusing on isolated case studies, workforce implications, technological

capabilities or competitive pressures. There is limited consolidated synthesis that evaluates the overall maturity of implementation within the industry.

Furthermore, the relationship between Lean principles and Industry 4.0 technologies in the South African automotive context is not systematically assessed. Although benefits such as productivity improvement and quality enhancement are frequently cited, the barriers and drivers influencing adoption, particularly skills gaps, cost constraints and global competitive pressures are discussed across studies without integration into a unified framework. This fragmentation limits strategic clarity for both policymakers and industry stakeholders.

Therefore, the purpose of this systematic literature review is to determine the extent of Industry 4.0 implementation within the South African automotive industry and to identify the primary benefits, barriers and drivers influencing its adoption. By consolidating and analysing peer-reviewed literature, this study seeks to provide a coherent overview of implementation maturity and to propose a structured framework that supports more coordinated Lean 4.0 progression within the sector.

2. Research Methodology

The research methodology followed for this scoping systematic literature review is based on the methodology outlined by Albliwi *et al* (2014) and will be detailed below:

2.1 Step 1 – Develop research purpose

The goal of this systematic literature review is to establish the extent of the implementation of Industry 4.0 within the South African automotive industry as well as determining the drivers, benefits and barriers to the implementation so that a literature informed framework can be produced.

2.2 Step 2 – Develop research protocol

The developed research protocol is shown in Table 1:

Table 1. Research protocol for systematic literature review

Purpose of the study	Investigate the extent and the potential for the implementation of Lean 4.0 in the South African automotive industry along with the potential benefits and hurdles to this, so that a literature informed framework can be produced.	
Inclusion criteria	• Literature that contains the keywords in the keywords row • Literature that provides insight to the implementation of Lean 4.0 in South African automotive industries and highlights the benefits and barrier • Articles must have relevance	
Exclusion criteria	• Non-English Studies • Lean-X studies • Retracted papers • Papers which do not discuss the points of interest	
Search databases	• Scopus • Web of science • IEEE Xplore	
Keywords	• South African automotive industry • Lean • Industry 4.0 • Fourth industrial revolution • Vehicle manufacturing	Boolean search string: ("South Africa" OR "South African") AND ((automo* AND industry*) OR ("vehicle manufacturing"))) AND (

		("Industry 4.0") OR (Lean* AND manufactur*) OR (Lean* AND "4.0") OR "Fourth industrial revolution" OR 4IR
Quality assessment criteria	• Duplicate articles to be removed • Studies must follow a coherent scientific method • Definitions and interpretations must be correct • Studies must be relevant to the research question.	

2.3 Step 3 – Establish relevance criteria

Papers will be considered relevant if they comply with the following criteria

- The papers use the keywords outlined in the above research protocol.
- The paper must discuss Lean and/or Industry 4.0 in the context of the automotive industry.
- The paper must be readable either in English or Afrikaans.
- Lean-X studies[1] are to be excluded.
- The methodology used for the paper must be transparent and follow the standard scientific method.
- The paper must be peer-reviewed.
- The paper must discuss the South African automotive industry specifically.
- No retracted papers will be considered.
- The paper should discuss the keywords and points of interest, rather than just using them in a passing remark.

2.4 Step 4 – Search and retrieve the literature

The search string shown in Table 1 was applied across the databases. Some minor formatting and command changes had to be made across the databases, however the logic remained the same across the searches. This resulted in a total of 36 articles across the 3 databases. Steps 4 to 6 are shown diagrammatically in Figure 1.

2.5 Step 5 – Selection of studies

The selection of papers was further refined by first excluding multiple duplicates found across the three databases. This exclusion resulted in 25 unique articles remaining. The included studies were then further reduced to 18 remaining articles by excluding articles according to the exclusion criteria in Table 1. The primary cause for exclusion was that some studies only mentioned Industry 4.0 as a passing remark or as a contextual element rather than elaborating or discussing its relationship to the automotive industry. Multiple Lean-X studies were also excluded from the SLR.

2.6 Step 6 – Quality assessment for relevant studies

The remaining 18 papers all satisfied the quality assessment as detailed in Table 1 and were found to be relevant according to the relevance criteria in step 3. Figure 1 summarises the article collection and assessment stages.

[1] Where Lean-X studies are those investigating variations on the traditional Lean philosophy such as Lean Six sigma

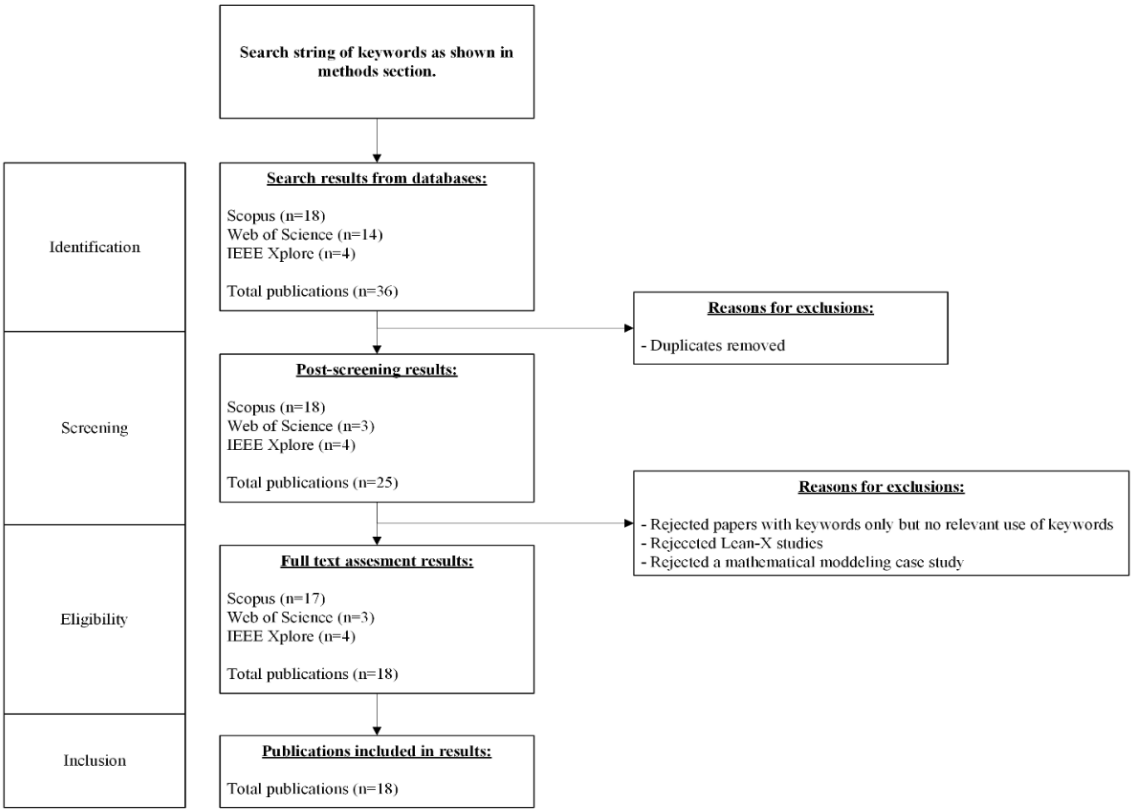

Figure 1. Process flow diagram of paper selection and inclusion

3. Results (Findings) and Discussion

This section will discuss the data that was collected. It should be noted that the reviewed studies primarily consist of case studies and empirical analyses, with fewer large-scale quantitative studies. While all included papers met the defined quality criteria, variation exists in methodological rigor, which may influence the generalisability of findings.

3.1 Step 7 – Data extraction

Once a full collection of studies was available for analysis, the articles were read in full and the data was extracted in accordance with the fulfilment of the purpose of the research. For determining the extent of the implementation of Industry 4.0 and lean within the South African automotive industry, the papers were read and classified into one of three categories:

1. Those suggesting a low level of Industry 4.0 implementation with the literature revealing continued dependence on Lean and Industry 3.0 manufacturing approaches.
2. Those where the literature shows evidence of emerging or partial Industry 4.0 adoption within a subset of firms.
3. Those where the literature reports widespread and mature integration of Industry 4.0 technologies across the industry.

Table 2 was created to show the results:

Table 2. Showing the level of Industry 4.0 implementation according to literature

Source	Sentiment	Evidence
(van Dyk and Pretorius, 2012)	No comment	Does not give an indication of degree of implementation
(Kirsten *et al.*, 2025)	Medium	States digitalisation in SA is in its "early stages"; many firms still rely on traditional supply chain practices while select managers use AI and IoT.
(Inyang *et al*., 2023)	Medium	Mentions SMS (Smart Manufacturing Systems) are "being established" but notes that I4.0 and SM are still in their "infancy".
(Mbatha and Mulongo, 2023)	Medium	Notes OEMs and Tier 1 have adopted AI, while Tier 2 and 3 suppliers remain "labour intensive" and underdeveloped.
(Macpherson and Werner, 2025)	Medium	Indicates organisations are "making strides" in automation, but human-robot collaboration (HRC) is still in its "infancy".
(Onu *et al*., 2023)	No comment	Explores technical mechatronic principles with general mentions of global firms like BMW.
(Andreoni and Anzolin, 2025)	Medium	Identifies that industrial robot adoption in SA is "incremental" and highly application-specific (e.g., metal commodities).
(Macpherson *et al*., 2022)	Medium	Explicitly states the automotive industry "has not fully adopted Industry 4.0 technologies" and HRC is in "infancy".
(Bakama *et al*., 2022)	Low	Focuses on a case where Lean Manufacturing is a "new approach" and production relies on basic Lean principles/waste elimination.
(Raveen and Shalini, 2011)	Low	Investigates a Durban organisation relying on Lean Manufacturing tools with no mention of Industry 4.0 technologies.
(Mund *et al*., 2015)	Low	Cites a "low level of automation" and a focus on centralized global designs with limited local digital engineering.
(Moeketsi & Letaba, 2022)	Medium	Describes technological capabilities as "inadequate to satisfactory" with a strategy focused on "incremental innovation" toward I4.0.
(Bag et al., 2021)	Medium	Describes digitalisation as being at a "nascent stage" in SA, despite the automotive sector leading other local industries.
(Anzolin & Andreoni, 2023)	Medium	Finds robot adoption is driven by rigid business strategies rather than full Industry 4.0 flexibility.
(Macpherson *et al*., 2023)	Medium	Notes an "absence of an ecosystem" to bridge the I4.0 gap, although major investments in automation are occurring.
(W. E. Macpherson, 2024)	Medium	Reaffirms that digitalisation is at a "nascent stage" and the industry has "not fully adopted" I4.0 technologies.
(Chigbu and Nekhwevha, 2022a)	Medium	Observes that while robotics and human workers collaborate, the transition is uncertain and affects job satisfaction.
(Chigbu and Nekhwevha, 2022b)	Medium	Reports high automation in specific areas (Body shop 100%, Paint shop 80%) but only 20% utilization in assembly.

Table 2 shows that most articles indicate a medium level of implementation. That is most articles indicate that there is an emerging or partial implementation of Industry 4.0 within the South African automotive industry. To further elaborate, the consensus among the articles is that within most of the South African automotive industry there are several domains where Industry 4.0 is highly implemented, whereas in others it is minimally implemented. Some articles identify that there have been recent major investments to implement Industry 4.0 more comprehensively. The articles also noted that transformation is driven more by business strategy rather than a technical plan to achieve full Industry 4.0 flexibility.

3.2 Step 8 –Analysis and synthesis of findings

To analyse the benefits, barriers and drivers of Industry 4.0 in the South African automotive industry, concept matrices were created checking which studies showed the most common benefits barriers drivers. This was done after identifying the most common benefits, barriers and drivers mentioned in the studies. Once these items were identified

the studies were then scanned again for using these terms as benefits, barriers and drivers with the results recorded in the concept matrices, starting with Table 3 showing the benefits of Industry 4.0 in the South African automotive industry.

Table 3. Showing the benefits to Industry 4.0 cited in literature

Reference	Productivity	Quality	Profit	Safety	Competitiveness	Waste Reduction	Upskilling	Lead Time	Visibility/Transparency	Sustainability
(van Dyk and Pretorius, 2012)	✓	✓	✓	✓	✓	✓	✓	✓	✓	
(Kirsten *et al.*, 2025)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
(Inyang *et al*., 2023)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
(Mbatha and Mulongo, 2023)	✓	✓	✓		✓	✓			✓	
(Macpherson and Werner, 2025)	✓	✓	✓	✓	✓		✓			✓
(Onu *et al*., 2023)	✓	✓	✓	✓		✓	✓		✓	✓
(Andreoni and Anzolin, 2025)	✓	✓	✓	✓	✓		✓			
(Macpherson *et al*., 2022)	✓	✓	✓	✓	✓		✓			
(Bakama *et al*., 2022)	✓	✓	✓		✓	✓	✓	✓		
(Raveen and Shalini, 2011)	✓	✓	✓		✓	✓	✓	✓	✓	
(Mund *et al*., 2015)	✓	✓	✓		✓	✓	✓	✓		
(Moeketsi & Letaba, 2022)	✓	✓	✓		✓	✓	✓	✓	✓	
(Bag et al., 2021)	✓	✓	✓		✓	✓	✓		✓	✓
(Anzolin & Andreoni, 2023)	✓	✓	✓	✓	✓	✓				
(Macpherson *et al*., 2023)	✓			✓	✓		✓			
(W. E. Macpherson, 2024)	✓		✓		✓		✓			✓
(Chigbu and Nekhwevha, 2022a)	✓	✓	✓	✓	✓	✓	✓			
(Chigbu and Nekhwevha, 2022b)	✓	✓	✓	✓	✓	✓	✓			

The results in Table 3 suggest that productivity is by far the most ubiquitous benefit. This is consistent with the characteristics of heavy industry, such as car manufacturing, as greater productivity naturally translates to greater profit. Profit is therefore also seen as the second most frequently mentioned benefit. A further valuable contributor to the greater success for the automotive industry is an improvement in quality which is mentioned as the third most prevalent benefit. The benefits least mentioned are a reduction in lead time, transparency and sustainability.

Table 4 presents the barriers found to the implementation of Industry 4.0 in the South African automotive industry:

Table 4. Showing the barriers to Industry 4.0 cited in literature

Reference	Skills & Knowledge Gap	High Costs & Investment	Resistance to Change	Infrastructure & Loadshedding	Data Security & Privacy	Systems Integration	Policy & Leadership	Job Security & Social	Benefit Quantification
(van Dyk and Pretorius, 2012)	✓	✓	✓				✓		✓
(Kirsten *et al.*, 2025)	✓	✓	✓	✓	✓	✓	✓	✓	
(Inyang *et al*., 2023)	✓	✓	✓		✓	✓			
(Mbatha and Mulongo, 2023)	✓	✓							
(Macpherson and Werner, 2025)	✓	✓	✓				✓	✓	
(Onu *et al*., 2023)	✓	✓	✓			✓	✓	✓	
(Andreoni and Anzolin, 2025)	✓	✓		✓		✓			
(Macpherson *et al*., 2022)	✓	✓	✓					✓	
(Bakama *et al*., 2022)	✓	✓	✓				✓		✓
(Raveen and Shalini, 2011)	✓		✓				✓		✓
(Mund *et al*., 2015)	✓					✓			
(Moeketsi & Letaba, 2022)	✓	✓	✓					✓	
(Bag et al., 2021)	✓								
(Anzolin & Andreoni, 2023)	✓	✓		✓		✓		✓	
(Macpherson *et al*., 2023)	✓	✓		✓					
(W. E. Macpherson, 2024)	✓							✓	
(Chigbu and Nekhwevha, 2022a)			✓					✓	
(Chigbu and Nekhwevha, 2022b)	✓	✓						✓	

For the barriers mentioned in literature, a skills and knowledge gap in the workers and workforce was found to be the most common barrier to a successful implementation of Industry 4.0. Secondly a high cost of investment is mentioned as a common impediment to Industry 4.0 implementation within the South African automotive industry. Another barrier that is unique among the most common barriers as it is possibly the most concerning from the point of policy making is that workers have shown significant resistance to the implementation of Industry 4.0 within the automotive industry. There is also little mention of data security and privacy concerns, although this may be more due to the logistical nature of the papers rather than a genuine reflection of actual concerns.

Table 5 presents the drivers for Industry 4.0 adoption as identified in the reviewed literature:

Table 5. Showing the drivers to Industry 4.0 cited in literature

Reference	Stakeholder & Regulation	Global Competition	Productivity	Quality & Precision	Cost & Profit Maximisation	Safety & Ergonomics	Customer Engagement	Innovation & Strategy	Talent & Skills Development
(van Dyk and Pretorius, 2012)	✓	✓		✓	✓				
(Kirsten *et al.*, 2025)	✓	✓	✓		✓		✓	✓	
(Inyang *et al*., 2023)	✓	✓	✓		✓			✓	
(Mbatha and Mulongo, 2023)		✓	✓	✓	✓		✓	✓	
(Macpherson and Werner, 2025)	✓	✓	✓	✓	✓	✓	✓	✓	✓
(Onu *et al*., 2023)	✓		✓	✓	✓		✓	✓	
(Andreoni and Anzolin, 2025)		✓	✓	✓	✓	✓			
(Macpherson *et al*., 2022)		✓	✓	✓	✓	✓	✓	✓	
(Bakama *et al*., 2022)		✓	✓	✓	✓		✓	✓	
(Raveen and Shalini, 2011)		✓	✓	✓	✓		✓		
(Mund *et al*., 2015)		✓	✓	✓					
(Moeketsi & Letaba, 2022)		✓	✓	✓	✓			✓	
(Bag et al., 2021)	✓	✓			✓		✓	✓	✓
(Anzolin & Andreoni, 2023)		✓	✓	✓	✓	✓		✓	
(Macpherson *et al*., 2023)	✓	✓	✓		✓			✓	✓
(W. E. Macpherson, 2024)	✓	✓	✓					✓	✓
(Chigbu and Nekhwevha, 2022a)		✓	✓	✓	✓	✓	✓	✓	
(Chigbu and Nekhwevha, 2022b)	✓	✓	✓	✓	✓	✓	✓	✓	

Table 5 shows that competitive pressure and the need to improve productivity are the most frequently cited drivers motivating the adoption of Industry 4.0 within the South African automotive industry. This aligns with the global competitive nature of the automotive sector, where firms are under continuous pressure to improve efficiency, reduce costs, and remain viable within international value chains. Another prominent driver identified across the studies is the pursuit of quality improvement and operational reliability. Several articles highlight that digitalisation and automation are increasingly viewed as necessary enablers for achieving consistent product quality, reducing defects, and meeting stringent OEM requirements. In addition, supply chain integration and visibility emerge as notable drivers, particularly in the context of global value chains where real-time information sharing and coordination are becoming increasingly important. External pressures, such as customer requirements and international industry standards, are also identified as key drivers in several studies. These pressures often originate from multinational parent companies or global OEMs, which compel local firms to adopt Industry 4.0 technologies to align with global manufacturing strategies. While sustainability and environmental considerations are mentioned less frequently as primary drivers, they are still present in the literature, often framed as secondary benefits rather than initial motivators. Overall, the literature suggests that Industry 4.0 adoption in the South African automotive industry is predominantly driven by economic and competitive considerations rather than policy mandates or long-term strategic digital transformation plans. This reinforces earlier findings that implementation is largely incremental and strategically selective, with firms prioritising technologies that deliver immediate operational or competitive advantages.

Based on the information gathered in Table 2, the current state of Industry 4.0 implementation within the South African automotive sector can be described as follows, business-driven, with clear instances of highly developed and sophisticated yet poorly integrated implementations within subsections of the automotive industry. Notably, the degree of implementation can also be described relative to the other industries within South Africa, specifically, the automotive industry is the leader within the country in Industry 4.0 implementation. These findings support the

conclusion that Industry 4.0's implementation within the South African automotive industry is at a medium level according to the definition in the start of 3.1.

The benefits identified in the literature pertaining to profitability and productivity are unsurprising, the concept of improving production that would otherwise have been executed by humans subject to human error, with automated machinery is uncontroversial and a known benefit to the automotive industry as is reaffirmed by the fact that economic gains are the most cited benefit. A notable relationship between benefits and barriers can be identified, that is that the benefit of upskilling workers immediately implies that there is an initial lack in workers' skills upon implementation if done too fast. This suggests that implementation should be done in either a phased approach or workers need to be intentionally upskilled before a major shift is executed. Finally, it is noteworthy that sustainability and transparency are the two least cited benefits to Industry 4.0 implementation. This represents a significant blind spot in literature or in the concern of companies as this shows that these benefits are not explored.

In terms of barriers the biggest and most immediately apparent barrier is the high financial cost of implementation. It is unclear whether the high cost being a significant barrier is due to implementation being particularly expensive within South Africa in absolute terms or whether due to manual labour being relatively affordable within South Africa it simply works out to be more affordable to retain manual systems, this is an area requiring further research. The major grouping of barriers that stands out is how Industry 4.0 interacts with workers within the automotive sector. As mentioned, there is a significant skills gap between workers and the requirements of Industry 4.0, workers also indicated a significant concern regarding job security. This concern connects with the skills gap as many workers come from low-income families and may be less inclined to be aware of upskilling opportunities or be less able to access them. This may explain the significant resistance from workers noted in literature, as they most likely question where they fit into Industry 4.0 and therefore regard it as a threat to their livelihoods. This underscores the importance of the industry not only educating its workers on Industry 4.0 and upskilling them, but also clearly affirming the workers' roles in the industry. Furthermore, a concerted effort should be made to make this education as accessible to the workers as possible to avoid a widening skills gap between workers of different economic statuses.

The biggest driver for the implementation of Industry 4.0 was found to be global competition. This indicates that the South African automotive industry is following a reactive approach to implementation rather than a proactive one. Regulations are also cited as a significant driver, though not as frequently as global competition. The next most cited drivers are all encouraged by profit maximization, greater productivity and efficiency, while there is lesser mention of the benefits of talent development and workplace safety for workers being an active driver of implementation. Research is therefore currently focusing on direct short-term drivers such as economic gain or pressure from global competition rather than considering the human aspects such as the safety and skills of the workers.

3.3 Literature based framework

The literature-based framework is structured into three consecutive phases. The first phase focuses on reducing or mitigating the barriers to implementation. This phase is prioritised, as proceeding with implementation while significant barriers remain would introduce unnecessary inefficiencies and hinder overall progress. The second phase aims to amplify the existing drivers of implementation. By strengthening these positive forces within the industry, the rate of implementation can be accelerated, and a more coordinated and sustained effort can be encouraged. The third and final phase is concerned with maximising the benefits of implementation. These phases are described in greater detail below:

Phase 1 – Given that funding is identified as a significant barrier, the initial step should involve closing the funding gap, either through budget reallocations or by attracting investment. Subsequently, the skills gap must be addressed. A coordinated effort should be undertaken by industry employers to equip workers with the necessary competencies to participate effectively in an Industry 4.0-integrated workforce. This initiative should deliberately ensure inclusivity, enabling participation regardless of workers' economic circumstances, thereby preventing the widening of skills inequality. Furthermore, collaboration with academic institutions is recommended to develop a structured framework for workforce education and training.

Phase 2 – This phase builds on the funding considerations identified in Phase 1. Stakeholders should be educated and informed about the necessity of Industry 4.0 implementation for maintaining the industry's global competitiveness. Such alignment is critical to ensuring a coordinated and sustained implementation effort. Engagement with government is also recommended to facilitate the development of supportive policies, including targeted incentives

and the expansion of special economic zones. A compelling case can be made for such support, given the industry's significant contribution to the economy, particularly in terms of employment. Additionally, the potential for improved worker education and development through Industry 4.0 implementation should be emphasised to garner support from worker-oriented organisations, such as trade unions.

Phase 3 – Industry 4.0 implementation has the potential to fundamentally transform the automotive sector. This transformation should be leveraged as an opportunity to restructure the industry and eliminate inefficiencies. In particular, the disruption associated with implementation can be utilised to embed Lean 4.0 (and potentially Lean 5.0) principles, thereby promoting a more human-centric and efficient industrial system. Through this process, South Africa can begin to position itself as a globally competitive player within the automotive industry.

The framework is summarised in Figure 2 below:

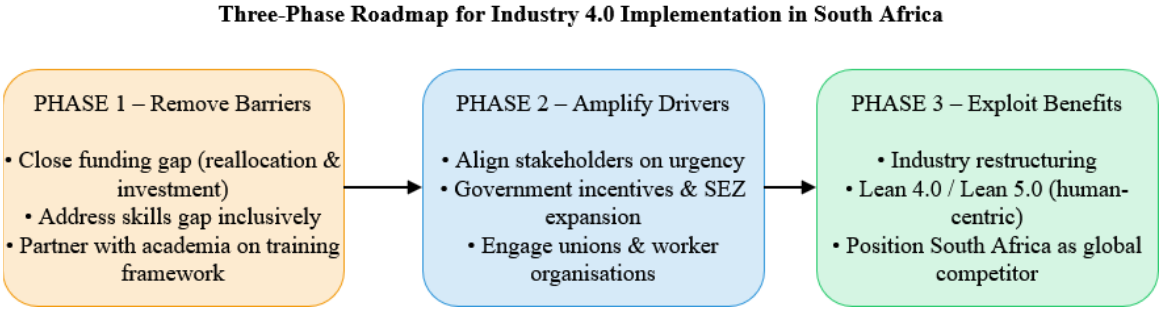

Figure 2. Proposed literature-based implementation framework

6. Conclusion

The objective of this study was to determine the extent of Industry 4.0 implementation within the South African automotive industry and to identify the primary benefits, barriers and drivers influencing its adoption. Through a structured systematic literature review of 18 relevant peer-reviewed studies, these objectives were met.

The findings indicate that Industry 4.0 implementation within the South African automotive sector can be classified as medium. Implementation is characterised by isolated pockets of advanced technological adoption rather than fully integrated digital transformation across the industry. While the sector remains one of the most technologically developed in South Africa, its progression toward Industry 4.0 is largely incremental and business driven.

The most frequently cited benefits relate to productivity, profitability and quality improvement, reaffirming that economic gains remain the dominant motivation for adoption. However, significant barriers persist, particularly skills gaps, high capital investment requirements and worker resistance linked to job security concerns. The dominant driver identified is global competitive pressure, suggesting that adoption is primarily reactive rather than strategically proactive.

The unique contribution of this study lies in consolidating fragmented literature into a coherent overview of implementation level, benefits, barriers and drivers specific to the South African automotive context. Furthermore, the proposed phased literature-based framework provides a structured pathway for more coordinated and sustainable Lean 4.0 implementation within the industry.

It is also proposed that future research explores the benefits Industry 4.0 implementation can offer the South African automotive industry with regards to improvements in sustainability and transparency as these areas were demonstrated to be under researched. Further research is also required to identify whether employers within the automotive industry are reluctant to deploy Industry 4.0 principles due to labour being more affordable than implementation or if the initial investment is too much for the industry to survive.

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Biographies

Johann Wahl is a first year Master's student in Industrial Engineering at Stellenbosch University. He holds a Bachelor's degree in Mechanical Engineering from Stellenbosch University. His academic work focuses on systems modelling, operational performance, and the evaluation of Industry 4.0 implementation in industrial environments. His current research includes conducting systematic literature reviews examining reported operational impacts such as productivity, quality, safety, sustainability, and competitiveness. He has worked on projects involving machine design, control systems, and mechatronic systems, with an emphasis on structured methodology and clear technical reporting. His research interests include digital transformation in industry, operational performance measurement, and the practical integration of advanced technologies into production and organisational systems.

Mia Mangaroo-Pillay is a Senior Lecturer in the Department of Industrial Engineering at Stellenbosch University in South Africa, where she engages in teaching, research and supervision within the fields of industrial engineering. She holds a PhD in Engineering. Dr Mangaroo-Pillay's research focuses on operational excellence, human-factors engineering, Lean philosophy and Industry 4.0/5.0.

Edward Davies is a senior academic and industry leader with extensive experience spanning automotive manufacturing, operations management, quality management, and strategic leadership. He currently serves as a Senior Lecturer (Extraordinary Appointment) at Stellenbosch University and lectures in the Postgraduate Diploma in Industrial Engineering at North-West University, where he teaches Quality Management and Business Process Engineering. In parallel with his academic contributions, Edward holds the position of Regional Aftersales Manager at Audi South Africa, where he operates at OEM level within a multinational automotive environment. His career spans diverse portfolios including pure engineering, automotive manufacturing technology, production systems, operations management, and OEM-level sales and marketing. He has developed specialist expertise in automotive aftersales operations at both OEM and dealer levels, combining technical insight with strategic and commercial acumen. Edward also serves as an External Examiner at Nelson Mandela University, examining doctoral research in Operations Management, MBA treatises, and master's-level engineering work, and moderating advanced Production Management modules. His previous academic involvement includes research in Lean systems and Water and Energy Efficiency, as well as co-supervision of postgraduate Industrial Engineering students and facilitation of final-year industry projects. He has been affiliated with the Unit for Energy and Technology Systems (UETS), contributing to research at the interface of engineering systems and sustainability.

Table 6: Response to reviewer feedback

Reviewer Feedback	Author Response
Duplicate references in tables (e.g., Chigbu & Nekhwevha, 2022)	The duplication has been corrected. Distinct entries are now labeled as (Chigbu & Nekhwevha, 2022a) and (2022b) to ensure clarity and consistency.
Some "medium" classifications may be subjective	The classification of "medium" implementation levels has been carefully re-evaluated, clarified and supported with evidence.
Figure 1 referenced but not included	Figure 1 has now been included in the manuscript and appropriately referenced.
"Lean-X studies" not defined	A brief definition of "Lean-X studies" has been added as a footnote to improve clarity.
Figures (Figure 1 & 2) missing from document	Both Figure 1 and Figure 2 have now been included and properly labeled in the manuscript.
Include missing figures	All previously missing figures have been incorporated into the revised manuscript.
Define unclear terms (e.g., Lean-X)	All previously unclear terms have been defined to improve readability and precision.
Expand discussion with comparisons to other countries	Due to the page limitation of the paper, a detailed comparative analysis with other countries was not included. However, this has been identified as a valuable direction for future research in the conclusion.
Include methodological quality discussion of studies	The methodological quality of included studies is addressed through the selection criteria and further discussed in the Results section. A more detailed discussion was considered but is limited by the page constraint and is suggested as future work.
Improve academic writing in some sections	The manuscript has been revised to improve academic tone, clarity, and overall writing quality.
Add table summarizing study types and evidence levels	While valuable, the inclusion of an additional summary table was not feasible within the page limit. This is acknowledged as a potential enhancement for future work.