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STRATEGIC ANALYSIS OF SUSTAINABLE LEAN MANUFACTURING IN THE UK ELECTRIC VEHICLE AUTOMOTIVE VALUE CHAIN

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Abstract

The UK's automotive supply chain is transitioning from internal combustion engines (ICE) to electric vehicles (EV) through lean manufacturing (LM) adoption of key trends and sustainable technologies, leading towards augmented industry growth across the nation and globe. However, manufacturing professionals and scholars have identified the scarcity of limited researched factors of constraints and innovative mitigation techniques examined in literature and industry, whereby successful LM is highly inadequate. The purpose of the study is to analyse the research gap within a case study of a UK manufacturing organisation regarding the scarcity in potential scope barriers cumulating the arise of lean failures, and to identify mitigation techniques of lean practices through critical analysis to aid in the establishment of drawing conclusions. Thus, the study depicts recommendations of LM development across the UK, ensuring maximum efficiency of a cradle-to-cradle ecosystem through net-zero driver enforcement. The conclusion of this study establishes how the UK automotive sector operates under the implored mechanisms by enforcing sustainability to attain net-zero within the EV segment, detailing the differing applied trends, tools, strategies, and necessary frameworks.

Key words: lean manufacturing; electric vehicles; net-zero; sustainability; and value chain.

Introduction

LM concepts have transpired worldwide, integrated into the modernised automotive processes whereby mass production and customisation have augmented over the years, transitioning to manufacturing EVs by integrating renewable energy forms to achieve a net-zero ecosystem whilst responding to societal demands (Bhamu and Singh Sangwan, 2014; Shi et al, 2019). Thus, Ciarniene and Vienazindiene (2012) delineate LM philosophy encourages sustainability principles of streamlining processes to minimise resource waste and non-value-added procedures, generating operational value through integrating collective strategies and tools, enhancing competitive advantages through multifaceted managerial mechanisms adopted from the Toyota Production System (TPS) entailing continuous improvement (Kumar et al, 2022; Sundar, Balaji, and Satheesh Kumar, 2014). The TPS was the first practical use of LM to ensure inventory and transformation stages were surrounding a cradle-to-cradle concept for an enhanced cost-effective system design, and functionality of

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efficiently minimising Muda through a just-in-time (JIT) and Jidoka system, limiting lead times (Gupta and Jain, 2013; Geraldo dos Santos, Vieira, and Balbinotti, 2015).

The scarcity of fossil fuels and environmental degradation imposed by globalisation is forcing organisations to conform to new regulatory requirements (Naeemah and Wong, 2022). Therefore, as the UK EV automotive corporations are shifting to sustainable means by propelling to be 100% carbon neutral by 2035, where it has been defined there are critiques of these newly adopted managerial strategies of LM key trends (GOV UK, 2023; Nordin, Deros, and Wahab, 2010). Over the past decade, there has been an increase in the automotive sector concerning EVs, regarding the need to mitigate environmental issues associated with emissions, by transitioning towards sustainable transportation, leading to the progression in obligatory research and enhancing technological advances of critical battery infrastructure for improved energy proficiency (Oye and Anthon, 2025).

The case study identified within the UK has transformed its supply chain (SC) into an electric ecosystem through the adoption of LM strategies to minimise its industrial footprint, whereby its production system assists in facilitating the entire manufacturing design, and value chain enhancement (McKie, Evans, and Jones, 2024). As such, the EV industry organisations are designated to become all-electric concerning its SC, with a focus on lean strategies and tool alignment to aid in the mitigation of associated emissions and unsustainable practices through its strategic applications (Carey, 2021). This study inflicts considerable implications for policy surrounding the UK Government and the manufacturing industry, as it was stated around 80% of new cars will be net-zero in emissions by 2030, which will augment to 100% by 2035 (The Department for Transport, Office for Zero Emission Vehicles, and Browne, 2024).

Literature Review

2.1 Automotive Supply Chain Sustainable Lean Tools, Strategies, and Trends

Lean Tools and Strategies

In the UK, globalisation has increased concerns within the triple bottom line paradigm, whereby the TPS conceptualised requirements for automotive corporations to minimise anthropogenic pollution and carbon footprint implications through sustainable practices and tools highlighted in Table 1, concerning LM for EV's as 20% of carbon dioxide (CO_2) emissions in the EU are generated from ICE vehicles (Cherrafi et al 2017; Ullah et al, 2025; Zope, Swami, and Patil, 2023). Dependent on Table 1 findings, the researcher's Singh and Singh (2009) and Manos (2007) emphasises Kaizen operates under human exertions metrics within firms to attain continuous improvement and amplified cultural productivity through leadership, employee, and managerial strategies for radical innovation to improve takt and lead times, aiding in systematically reducing inventory and production expenditures, developing customer value and enriching corporate objectives (Suárez-Barraza, Ramis-Pujol, and Kerbache, 2011; Palange and Dhatrak, 2021). Based on the review of prior research, Prayuda (2020) found the industry is dependent on environmental and behavioural interaction effectiveness, where Kumar et al (2022) reiterates Kaizen must be implemented through the entire value chain systems- from operations to ergonomics foundations- to successfully comply with imposed streamlined countermeasures to mitigate Muda and failures through managerial philosophies and ideological concepts of advancing employee practices and processes (Carnerud, Jaca, and Backstrom, 2018).

JIT operates under a pull system dependent upon information flow signals of meeting the customer upstream demand- moving away from forecasting- to minimise downstream lead times, unnecessary inventory, and enhancing ecological competitive advantages concerning quality and value optimisation, ensuring inbound and outbound logistics work in unison, profiting the triple bottom line (Othman et al, 2016; Araujo, Alves, and Romero, 2021). An investigation by Slack and Brandon-Jones (2019) shows LM prioritise pull systems in diminishing built-up inventory by repositioning resources through transmitted pull controls, whereby the SC operates on a flexible and transparent basis enhancing the synchronisation of flows and monetary conservancies (Htun, Maw, and Khaing, 2019; Slack, Brandon-Jones, and Burgess, 2022). According to Abdallah and Matsui (2007), JIT and pull production is flawed in conforming to sustainability means as top-management neglect supporting the integration across the value chain and conformig mechanisms to the internal corporate culture, away from the Japanese ethos, which influenced companies to adopt Kanban design to visualise the complex domains of demand, and authorise ordered workflow practices (Renna, Magrion, and Zaffina, 2013; Zarrar et al, 2021). As such, it eliminates the overconsumption of raw resources and operational waste regarding the transparency of the input-transformation-output phase by ensuring demanded work is pulled through the system when workstations are readily available, to reduce work in progress (WIP) and to maintain resource capacity (Damij and Damij, 2024).

Geraldo dos Santos, Vieira, and Balbinotti (2015) identify value stream mapping (VSM) in Table 1, which visualises mass operational and logistic flows through transparent demand monitoring to identify upstream and downstream bottlenecks, and enforce enhanced processes to vacate the eight types of Muda. Thus, it is applied throughout the entire value stream- not just singular systems- to enhance value-adding procedures by reducing WIP by 89% and lead times by 83%, reported by Singh et al (2010). Previous studies failed to evaluate how VSM successfully operates within the UK EV industry, yet Bhalwankar and Mastud (2014) detected it does so by managing information, problem solving, and physical transformation of material flows detailing the occurrence and magnitude of inefficiencies of communication and production, to directly implore new efficient quality designs of minimising waste pollution by 50% along with resource overconsumption (Choudhary et al, 2019; Chen and Meng, 2010; Sundar, Balaji, and Kumar, 2014).

Tools and Strategies	Oye and Anthony (2025)	Sharma, Nagar, and Agrawal (2013)	Geraldo dos Santos, Vieira, and Balbinotti (2015)	Palange and Dhatrak (2021)	Kumar et al (2022)	Zope, Swami, and Patil (2023)	Jamil and Razali (2015	Rewers, Trojanowska, and Chabowski (2016)	Abdulmalek and Rajgopal, (2007)	Sundar, Balaji, and Kumar (2014)
Just-In-Time	✓	✓		✓					✓	
Pull System			✓						✓	✓
Kaizen				✓	✓			✓		
Continuous Improvement	✓				✓			✓	✓	
Jidoka								✓		
VSM	✓	✓	✓	✓				✓	✓	✓
Six Sigma						✓				
5S					✓	✓		✓		
Continuous Flow		✓								
Kanban		✓		✓	✓			✓	✓	✓
Poka-Yoke				✓				✓		
DMAIC				✓						
TQM								✓	✓	
Line Balancing							✓			✓
Cellular Manufacturing		✓			✓				✓	✓

Table 1 – Lean Tools and Strategies

Lean Key Trends

Table 2 identifies the core LM trends that the industry has adopted, whereby Industry 4.0 enhances communication and information technologies to control autonomous workflows and operational practices efficiently, regarding production metrics by leveraging technological advancements for value-adding processes for sustainable optimisation, imitating market demand and changes to overcome implementation barriers (Kolberg, Knobloch, and Zuhlke, 2017; Rajak et al, 2025; Tortorella et al, 2021). Varela et al (2019) distinguish LM and sustainable mechanisms are optimised by Industry 4.0 due to the digitalisation and streaming solutions from integrating stakeholder values by analysing real-time metrics, supported by integrating technological infrastructures surrounding robotics, the Internet of Things (IoT), and automation with lean tools (Buer, Strandhagen, and Chan, 2018).

An investigation on the integration of LM trends established barrier prevention by transparently optimising processes seen within IoT of interconnected networking mechanisms, centralising on accumulating intelligence and data exchanges between machinery and systems, shared amongst human and industrial interfaces, encouraging enhanced intelligence of LM apparatuses (Marinelli et al, 2021; Anosike et al, 2021). Zarrar et al (2021) found that integrating LM tools and IoT expands SC

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communication and intelligence amongst systems and optimises decision-making capabilities through centralised interconnectivity networking, facilitating machinery monitoring to ensure Muda and breakdown mitigation, decreasing potential defects and carbon footprint metrics (Soori, Arezoo, and Dastres, 2023).

In 2019, within the automotive industry there was a robotic supply of 33% accordingly to Bartos et al (2021), as it allows corporations to configure to the 2030 net-zero targets of EV's through optimised automation processes to meet newly acquired technical advances of safety and environmental measures, to help with human labour and errors by increasing decision-making of quality outputs (Polonara et al, 2024). Marinelli et al (2021) disclose robotics present crucial functions of automation within modernised manufacturing, through efficient production outputs to minimise motion Muda of non-value-added movement of employees, as robots carry-out activities whilst refining manufacturing accuracy of streamlining repetitive operations, increasing efficiency and consistency by acknowledging bottlenecks, alleviating resource waste by preventing defects (Khan et al, 2024; Polonara et al, 2024).

Key Trends	Marinelli et al (2021)	Khan et al (2024)	Rajak et al (2025)	Tortorella et al (2021)	Buer, Strandhagen, and Chan (2018)	Varela et al (2019)	Kolberg, Knobloch, and Zuhlke (2017)	Anosike et al (2021)	Bogue (2022)
Industry 4.0	✓	✓	✓	✓	✓	✓	✓	✓	✓
Robotics	✓	✓		✓	✓	✓	✓		✓
AI		✓	✓						✓
IoT	✓	✓	✓	✓	✓	✓		✓	
Automation		✓	✓	✓	✓		✓	✓	✓
Additive Manufacturing	✓			✓		✓			✓
Cloud Computing			✓	✓		✓			

Table 2 – Lean Key Trends

As such, the researchers Alsmadi, Almani, and Jerisat (2012) dictate the adaptation of lean tools within EV SC of autonomous managerial impressions achieve sustainable measures by augmenting value-adding activities for optimal continuous improvement and change, whilst eliminating operational waste within the SC by reducing inventory and overconsumption of resources (Singh et al, 2013). Furthermore, the prior research and case study analysis supports a multi-dimensional approach of combining prudently selected LM tools and trends to fit corporate culture, dictating a positive impact on organisational performance by reducing non-value-adding processes, lead times, and costs whilst conforming to increased flexibility through sustainable paradigms (Bortolotti, Boscari, and Danese, 2015; Shah and Ward, 2003).

LM tools and trends depicted allow EV organisations to transform to a sustainable ecosystem through combining the key trends to facilitate value chain visibility through real-time data, permitting streamlined processes of optimal operations, Muda mitigation, and cultural superiority. Thus, it aids in firms in sustaining sustainable parameters through digital transformation by focusing upon customer wants to efficiently manufacture through automation practices, augmenting competitive advantages in waste mitigation through adapting the corrective technologies with applicable tools due to innovation and intelligence concerning controlling and monitoring (Kalsoom et al, 2021).

2.2 EV and Battery Drivers of Successful Lean Tool Implementation

Research documented globalisation and industrialisation expansion drove the implementation of LM tools to decrease economic impacts of structured functionality to enhance effective yet legitimate competitive advantage through enforcing the reduction of carbon footprints as in 2020, 21% of 191.2 million tonnes of UK waste was attributed by industrial waste (Hill, 2022; Food and Rural Affairs, 2024). Government regulation ensures an agenda of ESG goal compliance whilst influencing the drivers depicted in Table 3, whereby the UK EV manufacturers have begun to adopt renewable energy strategies focusing upon a CE of continuous improvement to attain net-zero across its value chain to effectively manage resources due to raw battery material scarcity, an reducing waste for environmentally-conscious consumer value (Gera et al, 2025). Kafuku (2019) discussed drivers construct the level and degree of sustainability that lean tools drive within operations management (OM), project management (PM) and supply chain management (SCM) due to the competitive and environmental challenges that must be attained to optimise JIT processes through continuously improving manufacturing apparatus, to productively eliminate non-value-adding practices that impact Muda reduction and cost effectiveness (Hallgren and Olhager, 2009; Patel et al, 2022). Lean production drivers have been extensively surveyed within prior research of the TPS, identifying it encourages EV manufacturers to ethically sustain demand with high-flexibility concerning agility to adapt to current markets and fluctuations, to reduce waste through quality foundations, potentially increasing market share, customer retention, and minimising fiscal charges (Qamar et al, 2020; Prakash and Kumar, 2011; Zhang, Narkhede, and Chaple, 2017).

A circular economy (CE) discipline has become increasingly researched due to its new concept of driving lean sustainability, encompassing a strategy that focuses on a cradle-to-cradle methodology of reusing waste whilst optimising resources regarding raw material scarcity, initiating a CLSC by recycling end-of-life battery materials for maximum value (Shekarian, 2020; Slack, Brandon-Jones, and Burgess, 2022). Asif et al (2012) narrate that a CLSC mitigates waste through control mechanisms of OM systems to augment value from recovered materials and value-adding processes, through hierarchical disassembly constructs, abiding by regulatory pressures and climate change measures (Bakker et al, 2010; Cherrafi et al, 2016). However, the execution of CLSC and CE is limited within the EV sector due to misconceptions of end-of-life batteries within a reversed logistics scenario of environmental support (Govindan, Soleimani, and Kannan, 2015), permitting the cast study to execute transformation strategies to maintain net-zero parameters by 2039 through eco-efficiency practices of flows (Battini, Bogataj, and Choudhary, 2017; Braungart, McDonough, and Bollinger, 2007).

Kumar et al (2019) argue that consumers purchase clean alternatives to ICE vehicles to limit hazardous pollution, and LM encourages firms to conform to social requirements, improving corporate sustainability consciousness, and cost-saving approaches, attaining competitive advantages and market value (Geissdoerfer et al, 2017). Therefore, the core drivers of LM integration include the extent of waste elimination through innovative streamlining of inventory flows, SC productivity in

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conjunction with customer expectations, and industrial competitiveness through decarbonisation enhancements (Hicks, 2007; Li, Liang, Cheng, 2021).

Drivers	Shekarian (2020)	Slack, Brandon-Jones, and Burgess (2022)	Gera et al (2025)	Braungart, McDonough, and Bollinger (2007)	Kafuku (2019)	Hallgren and Olhager (2009)	Damij and Damij (2024)
Closed-Loop Supply Chain	✓	✓					
Circular Economy	✓	✓					
Continuous Improvement					✓	✓	✓
Competitive Advantage			✓		✓	✓	
Net-Zero Strategy			✓	✓			
Increased Market Share Value						✓	
Reduction in Waste	✓	✓			✓		✓
Reduce Non-Value-Adding Activities		✓			✓		
Customer Retention and Satisfaction	✓		✓			✓	✓
Resource Management	✓	✓		✓	✓		✓
Cradle-to-Cradle				✓			
Fulfilling Demand Sustainably	✓	✓				✓	✓
Saving Costs (Recycling)	✓	✓	✓				
Triple Bottom Line			✓		✓	✓	
Environmentally Friendly			✓	✓	✓	✓	
Improved Manufacturing (Streamline)					✓	✓	✓

Table 3 – Lean Manufacturing Drivers

2.3 Recognising and Mitigating Lean Barriers of CLSC Failure

With considerations to the UK, the research by Mohanty, Yadav, and Jain (2007) and AlManei, Salonitis, and Xu (2017) identified that since the introduction of TPS in Japan, LM has been imitated due to drivers, yet derived problems occurred where tools employed must not be over-simplified and over-innovative, and align with the organisations existing flexibility and digitalisation. Zarbo (2012) details these barriers and failures are missing in literature- outlined in Table 4- due to misunderstandings and improper adoption of lean tools leading to 90% of firms failing in the process (Nordin, Deros, and Wahab, 2010; Mohanty, Yadav, and Jain, 2007) hence, Esfandyari and Osman (2010) outline the constraints categorised into subjects concerning executive and corporate management, cultural change, monetary limitations, and implementation planning which all interconnect within a CLSC ecosystem. Furthermore, Khan et al (2024) and Sharma (2014) identified many of the barriers, yet

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the cultural and innovative barriers were not seen across many other researchers, showcasing where there is a gap in the knowledge as some barriers are not seen as crucial to the development of lean, leading to the fact that less than 10% of UK corporations are successful due to limited continuous exertions and systematic expertise in understanding the barriers that led to the failures (Zhang, Narkhede, and Chaple, 2017).

Souza (2013) recognised the flow of resources within LM is dependent on the combination of lean tools to fulfil a CLSC, but scholar Swarnakar (2021) examined inadequate knowledgeable concepts and monitoring on the systemisation foundations is due to ineffective training, leading to internal resistance of adapting lean cultural aspects where top-management support is minimal, increasing expenses and resource overruns, limiting sustainable development. Hence, EV's present complexity to all systems of manufacturing components to attain sustainable transport and net-zero strategies which is why LM tools are implored into processes (Zope, Swami, and Patil, 2023), yet the scarcity of lean culture adoption and resistance to change affects managerial and social strategies of productivity and waste mitigation, leading to financial constraints (Sim and Rogers 2009; Elkhairi, Fedouaki, and Alami, 2019). A notable lack of EV empirical studies hinders the analysis on restrictions as it is evident barriers enforce lean tool instability of waste reduction and continuous improvement, largely regarding inefficient operations from poor communication and value chain transparency- especially between senior management- leading to machinery and process scheduling misuse affecting production quality and inventory balancing, whilst augmenting non-productive time usage (Sharma, 2014).

Core Barriers	Sharma (2014)	Kafuku (2019)	Khan et al (2024)	Mohanty, Yadav, and Jain (2007)	Alhuraish., Robledo, and Kobi (2017)	Elkhairi, Fedouaki, and Alami (2019)	Sim and Rogers (2009)	Marodin and Saurin (2015)	Sahwan, Rahman, and Deros (2012)
Poor Training	✓	✓	✓	✓	✓	✓	✓	✓	✓
Poor Knowledge	✓	✓	✓	✓	✓	✓	✓	✓	✓
Change Resistance		✓	✓			✓		✓	
Insufficient Communication	✓						✓	✓	
Poor Innovation and Adaptation		✓		✓					
Top Management Support		✓			✓	✓	✓	✓	
Operational Transparency	✓								
Inadequate Planning	✓		✓			✓	✓		
Inconsistent Resource Use	✓								✓
Production Errors	✓		✓						✓
Scarce Digitalisation			✓						
Capital Limitations			✓			✓		✓	
Inadequate Skill Set	✓	✓	✓	✓	✓	✓	✓		✓
Poorly Developed Strategies		✓							✓
Cultural Change	✓								✓

Table 4 – Lean Manufacturing Core Barriers

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Mitigation of Barriers

To mitigate and maintain the barriers, Marodin and Saurin (2015) designated a framework to establish barriers and analyse the overall consequential aspects and relationships, through interpretive structural modelling (ISM) to develop a mitigation action plan and provide contextual descriptions to realise failures. The challenges of lean are limited in literature according to Cherrafi et al (2017), so ISM methodology assists employees in visibly recognising unknown bottlenecks that stimulate lean failures through a hierarchical structural approach, pinpointing and collating the affinity interactions between constraints through relative magnitudes, imploring strategic metrics of mitigation tactics (Attri, Dev, and Sharma, 2013; Ullah et al, 2025). Also, constraints within the EV value chain are prevalent, where Khan et al (2024) critically evaluated that sufficient enforcement of training and expertise reduces the capability mismatch, imploring strategic implementation plans by adopting analytics for real-time data, increasing digitalisation and key trend technologies to minimise monetary difficulties and variability as delineated by Marodin and Saurin (2015), and Ahmad and Ismail (2017).

The three specified lean barriers are corporate culture, expertise, and unpractical top-management who do not comprehend lean initiatives by implementing it into the core internal strategies and processes, which presents an inability to critically enforce change, whereby knowledge and performance management must be analysed to attain optimal performance (Sahwan, Rahman, and Deros, 2012; Forghani and Tavasoli, 2017). Thus, Mostafa, Dumrak, and Soltan (2013) endeavour it is imperative within the industry to only adapt LM tools that correspond to the inner practices and frameworks to ensure maximum efficiency of Muda reduction and resource use, by employing and training the workforce to utilise new techniques of knowledgeable insights to accept the lean transition, aiding in the fulfilment of successful implementation factors described in Table 5 (Kumar et al, 2022).

Araujo, Alves, and Romero (2021) found through prior research top-management must ensure a clear definition of lean implementation strategies to enable support of embracing a mind-set of continuous improvement to develop solutions of unravelling Table 5 bottlenecks, by formal training apparatuses to optimise a culture of lean through strong leadership and value creation (Chan et al, 2019). Thus, it is dependent on people where managerial guidance must be enforced throughout the process to transparently communicate what operations are taking place, by adopting transformational leadership of a learning cultural paradigm of pro-active individuals with clear directions on attaining higher-performance and commitment, through open communication links of similar lean beliefs (Ahmad, and Ismail, 2017; Tortorella et al, 2021).

Successful Implementation Factors	Sahwan, Rahman, and Deros (2012)	Zope, Swami, and Patil (2023)	Marodin and Saurin (2015)	Ahmad and Ismail (2017)	Tortorella et al (2021)	Esfandyari and Osman (2010)	Forghani and Tavasoli (2017)
Lean Organisational Culture Transition	✓			✓	✓	✓	
Supporting Continuous Improvement	✓				✓		
Leadership Commitment	✓			✓	✓	✓	
Organisational Involvement	✓			✓	✓	✓	✓
Identifying Bottlenecks		✓	✓			✓	
Hybrid Operational System		✓					
Interpretive Structural Modelling			✓				
Financial Stability			✓	✓			
Expertise				✓			✓

Table 5 – Successful Implementation Factors

2.4 Tools to Enhance the 5 Lean Principles

The five principles enable efficiency mechanisms of lean regarding (1) customer values and expectations, (2) value stream analysis through mapping out the processes to determine value-adding activities, (3) enforcing flow by streamlining processes and bottleneck removal, (4) integrating a pull system focusing of customer demands to enable production, (5) and realising perfection through waste removal and process refinement (Sharma, Nagar, and Agrawal, 2013; Haque and James-Moore, 2004). Thus, it facilitates the implementation of strong organisational culture across the SC of long-term commitment by guiding how to continuously improve the EV processes by leveraging new and innovative recommendations, as it acts as a blueprint for manufacturing organisation on how to increase leaner and sustainable approaches across production and operations, to optimise a streamlined value chain and associated activities by attaining consumer and Muda value (Prakash and Kumar, 2011). In addition, the 5 principles operate under compatibility means across the markets, as it enforces industry understanding on what recommendations would align to enforce sustainability of decarbonisation, and enrich the EV's and battery chemistries for ideal quality and productivity standards, to maintain consumer and internal values of transitioning to net-zero (Chotaliya and Mehta, 2022). Research by Thangarajoo and Smith (2015) underlines the introduction of lean principles addressed barriers that transpire, usually between cultural aspects, against the decision-making of management to adapt to consumer value by ensuring streamlined operations, conforming to smooth material flows through a pull system of consumer demand whilst eliminating waste for optimal value generation.

Lean Recommendations

Total Productive Maintenance (TPM)

Guariente et al (2017) eludes EV market demands reached an all-time high due to the UKs 2050 strategy of net-zero emissions, which is forcing companies to adopt LM tools

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such as TPM to safeguard the triple bottom line by optimising waste through pollution mitigative tactics within SC and OM approaches, limiting excess monetary expenditure of breakdowns and defects (Chen et al, 2019). Previous literature identified TPM is a strategic method ignored in LM (Ju et al, 2015), yet it exploits equipment effectiveness and reliability through proactive maintenance of optimal liaisons between machinery and persons, concerning a comprehensive system delivery of continuous improvement of minimising Muda and expanding quality through zero defects, breakdowns, and accidents (Bon and Ping, 2011; McKone, Schroeder, and Cua, 1999). TPM will enhance the value chain when paired with the five lean principles, as the eight pillars must be combined throughout machinery, personnel, and the transformation stage to mitigate corporate objective implications, providing proliferation quality developments and process capabilities such as maximising the battery lifespan (Pacaiova and Izarikova, 2019; Prabowo and Adesta, 2019; Agustiady and Cudney, 2018).
The TPM concept concentrates on the production line of the EVs lifecycle with high efficiency and productivity, predominantly surrounding the batteries due to the complexity of cathodes and associated processes of manufacturing the components (Nallusamy and Majumdar, 2017), enabling top mechanisms of synergising the life span of equipment through proactive, predictive, and preventative maintenance of anomalies by involving all employees (Agustiady and Cudney, 2018; Chan et al, 2005). Therefore, it is acknowledged that EV manufacturers would benefit from TPM integration as it aligns with sustainable goals and corporate scope for for optimal quality, equipped with minimal SC production waste, ultimately increasing competitive advantages via performance metrics of enforcing Industry 4.0 technologies of automation (Brah and Chong, 2004; Hallioui et al, 2023; Xiang and Chin, 2021).

Jidoka and Poka-Yoke

Following the narrative of tools that could be utilise to enhance value chains, the development of Jidoka enforces safety and waste mitigation measures of automation and human error (Charron et al, 2015), stopping machinery and production lines once anomalies of malfunctions, inventory issues, and defects occur to ensure maximum efficiency, which once paired with Poka-Yoke, process control reaches 100% (Rewers, Trojanowska, Chabowski, 2016). Jidoka operates on autonomous automation of independently modifying control flows that observe the input-transformation-output process through sensors and systems, to simultaneously detect deviation sources against all machinery counterparts, augmenting a faultless strategy of value creation (Deuse et al, 2020). Poka-Yoke is a mistake-proofing method where manufacturing consists of complex procedures- both automated and human-operated- whereby the tool utilises mechanisms and algorithms of predictive evaluation to immediately identify critical mistakes prior to the final product, augmenting value and potentially achieving zero SC defects (Palange and Dhatrak, 2021; Wolniak, 2024). Therefore, the adoption of both Poka-Yoke and Jidoka implore enhanced value chain optimisation of value creation as the tools principles are complementary in creating efficient means of quality generation where Poka-Yoke prevents defects occurring, and Jidoka would detect and ultimately stop faults that may have later occurred, encouraging the systemisation of defect exposure and deterrence (Dudek-Burlikowska and Szewieczek, 2009).

2.5 EV's and Battery Benefits of Innovative Lean Practices

Analysing prior literature and evaluating the approaches within the previous sectors, Sharma, Nagar, and Agrawal (2013) expound LM encompasses many benefits as expressed in Table 6, such as the sustainable practices are influencing competitive advantage by refining productivity of quality enhancement from identifying non-value-added activities, leading to the elimination of waste and unnecessary resource consumption (Alhuraish, Robledo, and Kobi, 2017; Choudhary et al, 2019). Morrison (2023) obtained that market globalisation encouraged continuous improvement through LM to aid in beneficial outcomes through incorporating individual paradigms into an interconnected ecosystem of various lean applications, to achieve corporate and customer value regarding the collaboration of bottleneck identification, that minimise anomalies within SC and OM protocols, and conform to consumer needs (Ciarniene and Vienazindiene, 2012; Melton, 2005; Abdulmalek and Rajgopal, 2007). Due to the scarcity of raw materials, LM benefits the environment by providing sustainable practices and capabilities of visual controls where a JIT and pull systems ensures maximum efficiency of the resources utilised (Sharma, 2014; Sharma, Nagar, and Agrawal, 2013), which accomplished streamlined approaches through Kaizen abilities by viewing Muda as an undesirable consequence of poor OM protocols (Kumar et al, 2022).

Moreover, Khan et al (2024) illustrated the UK EV industry has elevated the use of LM that cooperate with robotics and automation systems which continuously improve repetitive activities by necessitating accuracy by observing bottlenecks through TPM, augmenting internal and external value, attaining competitive advantage through pairing advanced technology with lean operations and real-time data optimisation within complex SC and battery cathode intricacies (Oye and Anthony, 2025). The philosophy develops a paradigm of lean thinking, which encourages a highly flexible EV manufacturing approach to manage customer needs for enhanced value generation of high quality production with minimal to zero defects from bottlenecks, encouraging cost reductions due to the mitigation of unnecessary resource consumption through continuous improvement of VSM connections and activities (Qamar et al, 2020; Mohanty, Yadav, and Jain, 2007). Therefore, over 70% of corporations implementing lean methodology into production have established high value-adding flows within the SC concerning intense competition with the UK EV industry, whereby it has allowed the transition to attaining CLSC advantages through sustainable adoption and recycling of materials through a cradle-to-cradle framework of waste reduction systems of JIT control (Kafuku, 2019; Prakash and Kumar, 2011).

Benefits	*Melton (2005)*	*Prakash and Kumar (2011)*	*Khan et al (2024)*	*Qamar et al (2020)*	*Choudhary et al (2019)*	*Sharma (2014)*	*Ciarniene and Vienazindiene (2012)*	*Wesselkamper et al (2024)*	*Kafuku (2019)*	*Alhuraish, Robledo, and Kobi (2017)*
Sustainable Practices	✓		✓		✓			✓		✓
Competitive Advantage		✓	✓				✓			
Increasing Recycling			✓					✓		
Bottleneck Identification	✓		✓						✓	
Corporate and Customer Value	✓					✓	✓		✓	✓

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Identifies Non-Value-Added Activities	✓	✓			✓				✓	
Mitigating SC/Operational Waste			✓	✓	✓	✓		✓	✓	✓
Minimising Defects				✓		✓			✓	
Reduces Unnecessary Consumption					✓	✓	✓	✓	✓	
Streamline EV's and Batteries		✓	✓							
Enhance Productivity			✓			✓	✓			

Table 6 – Benefits of Lean Manufacturing

The Identification of Lean Innovation

Industry 4.0 and Line Balancing Valuation

A line balancing strategy for end-of-life batteries surrounds optimisation of recycling workflows and task assignments for disassembling and recovering raw materials through a reverse SC according to rates of production- increasing returns of investment- whereby costs of used resources can re-enter the SC for operational processes, and increase lean performance on quality and value generation through mitigating Muda. Prior literature reveals Lithium-Ion batteries (LIB) governs EV technology, yet transiting to lithium-ion-phosphate (LFP) cathodes under Industry 4.0 ensures augmented resource sustainability, leveraging automated systems such as digital twin technology within recycling operations, creating virtual models to test disassembly production of real-time monitoring to improve the recycling process (Ayerbe et al, 2022; Manuguerra et al, 2023). Thus, the combination of reverse SC, line balancing, and Industry 4.0 technologies augments analytics of real-time data to ensure optimal recovery through automation capabilities across the disassembly line (Didden et al, 2023), which will identify bottleneck occurrence and ensure a dispersion strategy, limiting WIP of cycle times (Jha and Khan, 2017; Hafizuddin et al, 2012).

Transitioning to Lithium-Ion-Phosphate (LFP) Batteries

LIBs have been reported to present unsustainable and environmental degradation implications, minimising the successful implementation of EV LM, due to the mining demands and pollution generated from scare raw materials such as cobalt, lithium, and graphite with a projected 2040 increase (European Commission, 2024), whereby between 1990-2019 the transport sector generated 17% of emissions (Niri et al, 2024). The transition to LFP batteries is documented in recent research, illustrating the removal of cobalt and nickel within its cathodes and presents lower costs of manufacturing and environmental concerns, along with an increased lifespan due to improved structural capabilities, with an expected market demand of 96,000 tons in 2025 as end-of-life LFP batteries retain 80% of capacity generating echelon utilisation for sustainable management and recovery (Zhao et al, 2024). Shi et al (2023) discovered the innovative change to LFP cathodes decreases carbon footprint aspects by maximising battery efficiency which in turn facilitates consumer value, reducing waste through a cradle-to-cradle framework within a CLSC as it enhances productivity within battery manufacturing and dissembling, especially as the batteries portray optimal longevity and fiscal incentives compared with LIBs (Lu and Zhu, 2024). Thus, scholars identified LFPs reduce failures of LM within the SC due the cathode stability, energy storage capacity, and safety protocols of thermal runaway of the battery chemistries, augmenting sustainable development of EV performance, defect mitigation, and recycling approaches to achieved a net-zero ecosystem (Shen et al, 2023, Quan et al, 2022; Chen, Li, and Bae, 2024).

Methodological Framework

A methodological framework is a structural application to assist in identifying the LM research gap, encompassing the systemisation of two data metrics concerning through epistemology foundations concerning qualitative to analyse variable generalisation, and quantitative method designs to generate and use data to assess relationships (Bahari, 2010), surrounding the research onion methodology with applications to a mixed-method framework (Al-Ababneh, 2020; Saunders, Lewis, and Thornhill, 2023; Mukhopadhyay and Gupta, 2014). Therefore, this study integrates both qualitative and quantitative approaches to strengthen the reliability and validity of its finding through the mixed-method integration of the methodology, utilising integrative measures and analysis to increase the counterpart synthesis of complementary results regarding the sharing of data and literature to ensure maximum validity and reliabilty of the lean phenomena (McKim, 2017; Dawadi, Shrestha, and Giri, 2021). Saunders, Lewis, and Thornhill's (2023) research onion is structurally articulate, allocating the formulation of optimal layers of philosophical and analytical illustration for research design concerning positivism and interpretivism philosophy, along with combinative utilisation of inductive (theory-building) and deductive (theory-testing) strategies and data collection techniques for comparative analysis a mixed-method approach by objectifying collated research through synergising all apparatuses (Sahay, 2016; Melnikovas, 2018; Omotayo and Kulatunga, 2015; Dainty, 2008).

Thus, qualitative metrics discovers knowledgeable insights and themes from empirical data- including interviews, secondary reports, and case studies- thereby enabling new theory development grounded in participants' perspectives, nature, and lived experience qualitative data permits the exploration of a person's nature and lived experience through evaluating dynamically complex humanist narratives into a common social variable (Alshenqeeti, 2014; Azungah, 2018; Creswell and Creswell, 2022). Conversely, quantitative research from the survey development of a structured measurable instrument to produce numerical data consisting of statistical trend patterns that enable theoretical proposition testing through measurables and quantifiable evidence (Taherdoost, 2022), which has been observed to be easily quantified. Bahari (2010) differentiates philosophy paradigms in line with the data types regarding interpretivism which is essentially a socially constructed phenomenon of contextualising beyond anthropological actions through reviewing cultural perceptions and behavioural aspects concerning qualitative contexts of reality foundations regarding preconceptions, prioritising social constructs concerning the interviews, case studies, and secondary literature (Mwita, 2025; Chowdhury, 2014). As such, positivism is an independent paradigm illustrating the prominence of unbiassed measurement of numerical and scientifically verified quantitative data in reality, to ensure empirical validity of knowledge through objective epistemology to ensure the dissolution of researchers applying personal value systems utilising and generalising survey and analytical data (Ali, Shah, and Shah, 2021; Alharahsheh and Pius, 2020).
The qualitative examination of secondary scholarly reports and 6 interview responses, will utilise content analysis to generate initial codes to identify recurring phrases to assess whether respondents' views align with industry knowledge (Oloke and

Abdallah, 2025) through an inductive approach of systematically theorising from data and theory adoption by interpretivism, expressing coding applications to supply phenomena generalisations and patterns driven by app4raisal objectives (Thomas, 2006; Kumar, 2024). Additionally, with concerns to the 40 quantitative survey findings that will be analysed, Yuwono and Rachmawati (2023) illustrate the adoption of a deductive approach will test existing theories through the analysis of raw data regarding the hypothesis's development, highting whether prior theories in literature were correct in raw statistics collated. Thus, Kaushik and Mathur (2014) detailed analysing 40 quantitative survey findings exploring LM areas identified in the literature permits descriptive analysis of positivism philosophical domains, exploring statistical observations collated from descriptive statistics of data inferences through measuring central tendencies to quantify a single measurement through the mode, mean, median, and standard deviation (SD) to depict statistical variations (Croucher and Cronn-Mills, 2015), as detailed in the formula below.

$$\sigma^2 = \sqrt{\frac{\sum (X - Mean)^2}{n-1}}$$

Mood's Median Test is a non-parametric method compare the medians of two or more independent samples to highlight sognifcant statistical differences, to test the degree of either the null or alternative hypothesis through utilising a chi-square statistic formula below (AlAita, Aslam, and Smarandache, 2024; Franke, Ho, and Christie, 2012).

$$\chi^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i},$$

The chi-square test evaluates discrepancies between observed and expected frequencies that derive a p-value, whereby when lower than 0.05 a variable relationship is determined proving the alternative hypothesis, and a value above this threshold indicates independence attesting the null hypothesis, whereby degrees of freedom (DF) reflect statistical distributions of how many values can vary without affecting the contingency table totals (Hayes, 2024; Vidgen and Yasseri, 2016).

Results and Discussions

4.1 Lean Tools and Trends Analysis

The literature identified several lean tools- kaizen, JIT, pull system, VSM, and kanban- that EV manufacturers adopt within its SC through several identified reports which were evaluated to increase continuous improvement and competitive advantages within the industry (Duque and Capdavid, 2007; Othman et al, 2016), as seen with the quantitative analysis of the most efficient tools of strongly agree parameters concerning JIT (52.5%), pull systems (47.5%), and kaizen (47.5%). The average mean operated between 1.70 to 1.97 relating to strongly agree and agree (1.70-1.97), with a most common response of 1.00 of strongly agree, concerning Kaizen, JIT and a pull system. As such, with relation to the duration of individuals utilising these tools within industry showcased the most common period is frequently with a 45% statistic, along with 25% concerning always, closely followed by 20% for sometimes, and 10% regarding rarely underpinning LM is always utilised with the EV market. Thus, this was also heavily consistent within the case study interview participants evaluating the applications, expressing the sustainable LM tools augment value and quality expectations as the tools mitigate Muda through defect identification of streamlined processes (Sharma, Nagar, and Agrawal, 2013; Dennis, 2015).

Moreover, with relation to key trends it was identified that technological advancements and digital transformations help to mitigate barriers and environmental concerns through centralised interconnectivity networking, to facilitate machinery monitoring to mitigate Muda within LM (Marinelli et al, 2021; Polonara et al, 2024; Kalsoom, et al, 2021). Additionally, this was perceived through the survey data as it identified automation received the highest variable of strongly agree at 60% followed by robotics (52.5%), Industry 4.0 (45%), and IoT (42.5%) presenting that the trends have been adopted, transitioning to LM processes through enhanced monitoring and control (Kalsoom, et al, 2021). Through the analysis of the interview responses, it interlinks with the prior research underlining the be consistent need to enforce such tools to increase efficiency, continuous improvement, and waste reduction throughout the ecosystem along with manufacturing processes to abide by the minimisation of environmental degradation activities, showcasing what the tools mitigate and attain within industry (Forghani and Tavasoli, 2017; Rewers, Trojanowska, and Chabowski, 2016).

4.2 Lean Driver Groups

Prior literature highlights drivers for implementing tools that improve resource and cost efficiency, productivity, and conforming to consumer alignment, while minimising carbon footprints through a closed-loop supply chain (CLSC) of waste mitigation practices, in line with net-zero governmental regulations (Hallgren and Olhager, 2009; Patel et al, 2022; Hill, 2022), whereby the interviews and survey reflected similar priorities. The qualitative data emphasised several drivers' concerning cost effectiveness, customer loyalty, quality, and waste elimination, aligning with literature findings showing an effective relationship link between industry and literature identified in Table 2 (Qamar et al, 2020). Also, survey results aligned with qualitative secondary reports showing frequent utilised drivers of customer retention (87.5%), waste reduction (82.5%), resource management (77.5%), and net-zero strategies (70%). However, Shekarian (2020) identified a newly emerged core driver of CLSC and circular economy (CE), which diverged from industry domain experiences of increasing recycling means. As such, the highest identified drivers within the quantitative paradigm were net-zero (52.5%), waste reduction (50%), and resource management (40%). The mean fluctuated across the driver groups whereby competitive advantage (2.05), CLSC (2.35), and increased market share value (2.20) attained a mean between 2 and 3 consisting of often and occasionally, showcasing these drivers were the least adopted, yet waste reduction had the lowest mean of 1.75, a median of 1.50, and a 1.00 mode delineating it was the most used driver concerning always and often metrics.

4.3 LM Barriers Causing Failures

LM has many barriers that lead to failures of implementation, as identified in the literature, concerning only 10% of firms in the UK are successful, due to constraints regarding managerial support, poor training, cultural change with relation to change resistance, and poor planning (Zhang, Narkhede, and Chaple, 2017), but it presented similar failure rates within the industry as 80% of survey participants firms have experienced failures. This was statistically significant within the interview, as overall, 88% of interviewee responses on barriers surrounded internal applications of employees, such as lack of engagement (17%), change resistance (17%), and poor top-management support (12%), aligning with prior literature expressed (Sim and Rogers 2009; Elkhairi, Fedouaki, and Alami, 2019). Moreover, it was identified that the alignment within the quantitative data presented similarities with qualitative data regarding top-management, and literature concerning strongly agree barriers of poor training (62.5%) and inadequate planning (52.5%). The literature demonstrated barrier mitigation measures such as increasing expertise, bottleneck identification, and fiscal management according to Khan et al (2024), which provided similarities within the survey statistics showcasing the highest 'very effective' mitigation response regarded expertise (70%) and identifying bottlenecks (67.5%).

4.4 The 5 Lean Principles and Innovative Tool Adoption

There are several recommendations that align with the literature review and prior research on lean recommendations, with a focal point of core activities that are closely related to LM, which showcase a high correspondence through the 5 lean principles of aligning internal processes to attain an enhance sustainable ecosystem (Chotaliya and Mehta, 2022). The five principles were identified to increase efficiency amongst the value chain as depicted by Sharma, Nagar, and Agrawal (2013) through lean applications of continuous improvement, yet within the survey it was identified that the principles were not utilised as much as prior literature stated due to an average mean between 2.00 (often) and 2.42 (occasionally), with the highest adopted principles being flow whereby 47.% of survey participants utilised it always, and lowest principle was pull at 25% due to non-operational roles. As such, with the identification of further adoption of TMP, Jidoka, and Poke-Yoke, which is enforced to facilitate the reduction of errors and defects across the production line through proactive and automated maintenance (Ju et al, 2015; Dudek-Burlikowska and Szewieczek, 2009), the interviews identified lean tools would increasingly allow firms to adopt a CLSC (14%) to minimise Muda, consistent with the literature. Furthermore, industry professionals also indicated the adoption of the three tools would be an innovative solution, concerning a combined strongly agree and agree variables concerning Poka-Yoke (87.5%), TPM (87.5%), and Jidoka (77.5%).

4.5 EV Benefits and Battery Evaluation

The analysis of prior literature underlines benefits of LM for the manufacturers focusing on sustainable practices, Muda mitigation, and customer focus with the notion of increasing competitive advantage (Choudhary et al, 2019), especially with concerns to reducing unnecessary consumption and reduction in waste as depicted by Khan et al (2024), whereby these benefits were attained across the EV industry concerning majority of the participants responses. The quantitative statistics acknowledged reducing unnecessary consumption and mitigating waste had an augmentation of strongly agree variables amounting to 62.5% for consumption and waste mitigation, meaning LM benefits encompassed a mean between 1 and 2 showcasing responses were varied between strongly agree and agree, which is seen within the mode of 1.00. Also, the median was 1.00 for sustainable practices, streamlining operations, mitigating waste, and reducing unnecessary consumption due to an increased strongly agree metric, whereas minimising defects compiled a median of 1.50, yet increasing a CE and minimising non-value-added activities was 2.00 due to more varied responses. Furthermore, the literature review identified an innovative solution of integrating line balancing and Industry 4.0 to permit the analysis of real-time data to optimise the identification of bottlenecks through automated means, whereby the quantitative metrics expresses that 90% of individuals inputted the need to innovate and adopt this recommendation to attain LM benefits (Didden et al, 2023).

As such, Shi et al (2020) delineated that LIBs are unsustainable- seen within the survey selection as 62.5% of industry professional agreed- increasing the urge to transition to LFPs more stable and sustainable chemistries. Also, it is apparent that 67% of the interviewees attained limited information on the new cathodes, which presented similar results within the survey, but was more widely acknowledged within the industry with a combined strongly agree and agree metric of 32.5%, acknowledging the need to adopt new battery cathodes to minimise defects (Shen et al, 2023, Quan et al, 2022; Chen, Li, and Bae, 2024). There were several themes determined amongst the drivers of LFP adoption, where 18.18% acknowledged it created enhanced safety, resource security due to abundance of materials, cost efficiency, and longevity with respect to the lifespan of LFP batteries, all of which would increase competitiveness across the automotive market (Zhao et al, 2024; Shi et al, 2023).

Conclusion

Lean tool implementation enables corporations to streamline processes, eliminating non-value-adding activities to maximise value, quality, and sustainable performance objectives effectively driving innovative mechanisms through Muda mitigation, optimising operational efficiency by adopting Kaizen, JIT, and pull systems. Furthermore, LM aligns with key industry trends, as the integration of SC digitalisation and technological advancements has significantly enhanced the competitive advantages of EV and battery practices through viable applications. LM attains many drivers that encourage EV firms to adopt the tools advantages to help meet government regulations concerning net-zero parameters by 2050 through ethical and environmental standards, whereby the most sought-after drivers of EV production are waste reduction within the CLSC to maintain competitive advantages and ensure maximised customer retention. Howbeit, such adoption must be consistently implemented and transpired within a lean culture of high expertise and competent organisational support which were identified as the top constraints leading to failures, permitting sustainable transitioning to attain net-zero targets efficiently by managing barriers through introducing mitigation frameworks to adopt a cradle-to-cradle SC, in compliance with the lean philosophy.

The five principles are applied within lean approaches, yet inconsistencies remain hindering the successful integration of LM within a circular economy therefore, to strengthen outcomes, the additional adoption of TPM, Jidoka, and Poka-Yoke will increase quality extremity to mitigate Muda across the value chain, through the minimisation and eradication of defects and errors. Thus, LM provides significant benefits to the UK manufacturing industry, with Industry 4.0 integration with line balancing offering the potential to redefine organisational productivity. However, LIBs undermine LM's waste-mitigation goals due to their reliance on scarce raw materials that drive mining and environmental degradation, yet transitioning to LFP batteries could reduce these unsustainable practices, yet limited knowledge of cathode chemistries continues to hinder progress. Overall, LM provides significant industry benefits by amalgamating innovative approaches by integrating Industry 4.0 within line balancing, along with transitioning to LFP batteries to minimise unsustainable practices as LIBs counteract LM's aims of mitigating waste because the chemistries and cathodes require scarce raw materials- influencing environmental degradation- yet there is a lack of knowledge surrounding the LIB cathode chemistries, hindering the adoption.

Recommendations

Many recommendations could be subjected to this research, yet the main influential aspects are that it underpins to scholars the areas that are sparse, underlining the key successful considerations that lean tools need to be consistently implemented and transpired within a lean culture of LM high expertise consisting of competent organisational support, with constant monitoring of potential bottlenecks to limit failures, especially regarding batteries to determine a sustainable transition to attain the net-zero targets more efficiently. Also, this study inflicts considerable implications for policy surrounding the UK Government, thus the identification into this research gaps will allow Parliament to identify where lean failures are occurring that could potentially impact this new agenda, ensuring maximum evidence-based policies to mitigate inconsistencies, and encourage national priorities on these areas identified.
Additionally, it aids in permitting the UK EV industry with increased knowledge around the fast-moving value chain by providing value insights, as this research identifies the research gap of lean failures, but also the barriers and constraints that influence the unsuccessful completions, with additional studies into the core tools, benefits, drivers, and battery innovations that influence failure mitigation apparatuses.

References

Abdallah, A.B. and Matsui, Y. (2007) 'The relationship between JIT production and Manufacturing strategy and their impact on JIT performance', *Proceedings of the 18th Annual Conference of Production and Operations Management Society*, Dallas, Texas, 4-7 May. Available at: https://www.researchgate.net/publication/228357693_The_relationship_between_JIT_production_and_Manufacturing_strategy_and_their_impact_on_JIT_performance (Accessed: 23 July 2025).

Abdulmalek, F.A. and Rajgopal, J. (2007) 'Analyzing the benefits of lean manufacturing and value stream mapping via simulation: a process sector case study', *International Journal of Production Economics*, 107(1), pp. 223-236. Available at: https://doi.org/10.1016/j.ijpe.2006.09.009

Agustiady, T.K. and Cudney, E.A. (2018) 'Total productive maintenance', *Total Quality Management and Business Excellence*, pp. 1-8. Available at: https://doi.org/10.1080/14783363.2018.1438843

Ahmad, S.A.S. and Ismail., W.K.W. (2017) 'Lean manufacturing, culture, lean culture', *Journal of Business and Management*, 1(1), pp. 6-14. Available at: http://www.ijbmjournal.com/uploads/2/6/8/1/26810285/azuan__06-14_.pdf (Accessed: 24 July 2025).

Al-Ababneh, M.M. (2020) 'Linking ontology, epistemology and research methodology', *Science and Philosophy*, 8(1), pp.75-91. Available at: http://dx.doi.org/10.23756/sp.v8i1.500

AlAita, A., Aslam, M. and Smarandache, F. (2024) 'A new Mood's median test for imprecise data', *International Journal of Analysis and Applications*, 22(95), pp. 1-11. Available at: https://doi.org/10.28924/2291-8639-22-2024-95

Alharahsheh, H.H. and Pius, A. (2020) 'A review of key paradigms: positivism VS interpretivism', *Global Academic Journal of Humanities and Social Sciences*, 2(3), pp. 39-43. Available at: https://gajrc.com/media/articles/GAJHSS_23_39-43_VMGJbOK.pdf (Accessed: 28 July 2025).

Alhuraish, I., Robledo, C. and Kobi, A. (2017) 'A comparative exploration of lean manufacturing and six sigma in terms of their critical success factors', *Journal of Cleaner Production*, 164(October), pp. 325-337. Available at: https://doi.org/10.1016/j.jclepro.2017.06.146

Ali, M., Shah, A.A. and Shah, S.A.A. (2021) 'Positivism and interpretivism', *Qlantic Journal of Social Sciences*, 2(1), pp. 20-26. Available at: https://doi.org/10.55737/qjss.928180731

AlManei, M., Salonitis, K. and Xu, Y. (2017) 'Lean implementation frameworks: the challenges for SMEs', *Procedia CIRP*, 63, pp. 750-755. Available at: https://doi.org/10.1016/j.procir.2017.03.170

Alshenqeeti, H. (2014) 'Interviewing as a data collection method: a critical review', *English Linguistics Research*, 3(1), pp. 39-45. Available at: https://doi.org/10.5430/elr.v3n1p39

Alsmadi, A., Almani, A. and Jerisat, R. (2012) 'A comparative analysis of lean practices and performance in the UK manufacturing and service sector firms', *Total Quality Management and Business Excellence*, 23(4), pp. 381-396. Available at: https://doi.org/10.1080/14783363.2012.669993

Anosike, A., Alafropatis, K., Garza-Reyes, J.A., Kumar, A., Luthra, S. and Rocha-Lona, L. (2021) 'Lean manufacturing and internet of things- a synergetic or antagonist relationship?', *Computers in Industry*, 129(August), pp. 1-15. Available at: https://doi.org/10.1016/j.compind.2021.103464

Araujo, A., Alves, A.C. and Romero, F. (2021) 'Barriers to lean and pull system implementation: a case study', (from the 9th Manufacturing Engineering Society International Conference, Gijon, Spain, 23-25 June), *IOP Conference Series: Materials Science and Engineering*, 1193, pp. 1-9. Available at: https://doi.org/10.1088/1757-899X/1193/1/012048

Asif, F.M., Bianchi, C., Rashid, A. and Nicolescu, C.M. (2012) 'Performance analysis of the closed loop supply chain', *Journal of Remanufacturing*, 2(4), pp. 1-

21. Available at: https://link.springer.com/article/10.1186/2210-4690-2-4 (Accessed: 24 July 2025).

Attri, R., Dev, N. and Sharma, V. (2013) 'Interpretive structural modelling (ISM) approach: an overview', *Research Journal of Management Sciences*, 2(2), pp. 3-8. Available at: https://www.isca.me/IJMS/Archive/v2/i2/2.ISCA-RJMS-2012-054.pdf (Accessed: 23 July 2025).

Ayerbe, E., Berecibar, M., Clark, S., Franco, A.A. and Ruhland, J. (2022) 'Digitalization of battery manufacturing: current status, challenges, and opportunities', *Advanced Energy Materials*, 12(17), pp. 1-24. Available at: https://doi.org/10.1002%2Faenm.202102696

Azungah, T. (2018) 'Qualitative research: deductive and inductive approaches to data analysis', *Qualitative Research Journal*, 18(4), pp. 383-400. Available at: https://doi.org/10.1108/QRJ-D-18-00035

Bahari, S.F. (2010) 'Qualitative versus quantitative research strategies: contrasting epistemological and ontological assumptions', *Sains Humanika*, 52(1), pp. 17-28. Available at: https://doi.org/10.11113/sh.v52n1.256

Bakker, C.A., Wever, R., Teoh, C. and De Clercq, S. (2010) 'Designing cradle-to-cradle products: a reality check', *International Journal of Sustainable Engineering*, 3(1), pp. 2-8. Available at: https://doi.org/10.1080/19397030903395166

Bartos, M., Bulej, V., Bohusik, M., Stancek, J., Ivanov, V. and Macek, P. (2021) 'An overview of robot applications in automotive industry', *Transportation Research Procedia*, 55, pp. 837-844. Available at: https://doi.org/10.1016/j.trpro.2021.07.052

Battini, D., Bogataj, M. and Choudhary, A. (2017) 'Closed loop supply chain (CLSC): economics, modelling, management and control', *International Journal of Production Economics*, 183(B), pp. 319-321. Available at: https://doi.org/10.1016/j.ijpe.2016.11.020

Bhalwankar, M. and Mastud, S. (2014) 'Applying value stream mapping for improvements in automotive seat manufacturing processes', *International Journal of Mechanical Engineering and Robotics Research*, 3(4), pp. 164-177. Available at: https://www.ijmerr.com/uploadfile/2015/0407/20150407033247628.pdf (Accessed: 24 July 2025).

Bhamu, J. and Singh Sangwan, K. (2014) 'Lean manufacturing: literature review and research issues', *International Journal of Operations and Production Management*, 34(7), pp. 876-940. Available at: https://doi.org/10.1108/IJOPM-08-2012-0315

Bogue (2022) 'The changing face of the automotive robotics industry', *The Industrial Robot*, 49(3), pp. 386-390. Available at: https://doi.org/10.1108/IR-01-2022-0022

Bon, A.T. and Ping, L.P. (2011) 'Implementation of total productive maintenance (TPM) in automotive industry', *IEEE Symposium on Business, Engineering and Industrial Applications (ISBEIA)*, Langkawi, Malaysia, 25-28 September. Available at: https://doi.org/10.1109/ISBEIA.2011.6088881

Bortolotti, T., Boscari, S. and Danese, P. (2015) 'Successful lean implementation: organizational culture and soft lean practices', *International Journal of Production Economics*, 160(February), pp. 182-201. Available at: https://doi.org/10.1016/j.ijpe.2014.10.013

Brah, S.A. and Chong, W.K. (2004) 'Relationship between total productive maintenance and performance', *International Journal of Production Research*, 42(12), pp. 2383-2401. Available at: https://doi.org/10.1080/00207540410001661418

Braungart, M., McDonough, W. and Bollinger, A. (2007) 'Cradle-to-cradle design: creating healthy emissions – a strategy for eco-effective product and system design', *Journal of Cleaner Production*, 15(13-14), pp. 1337-1348. Available at: https://doi.org/10.1016/j.jclepro.2006.08.003

Buer, S-V., Strandhagen, J.O. and Chan, F.T.S. (2018) 'The link between Industry 4.0 and lean manufacturing: mapping current research and establishing a research agenda', *International Journal of Production Research*, 56(8), PP. 2924-2940. Available at: https://doi.org/10.1080/00207543.2018.1442945

Carey, N. (2021) 'Jaguar cars to go all-electric by 2025 as JLR plans full range of e-models by 2030', *Reuters*, 15 February. Available at: https://www.reuters.com/article/technology/jaguar-cars-to-go-all-electric-by-2025-as-jlr-plans-full-range-of-e-models-by-20-idUSKBN2AF0OX/ (Accessed: 21 July 2025).

Carnerud, D., Jaca, C. and Backstrom, I. (2018) 'Kaizen and continuous improvement - trends and patterns over 30 years', *The TQM Journal*, 30(4), pp. 371-390. Available at: https://doi.org/10.1108/TQM-03-2018-0037

Chan, F.T.S., Lau, H.C.W., Ip, R.W.L., Chan, H.K. and Kong, S. (2005) 'Implementation of total productive maintenance: a case study', *International Journal of Production Economics*, 95(1), pp. 71-94. Available at: https://doi.org/10.1016/j.ijpe.2003.10.021

Chan, S.W., Ismail, F., Ahmad, M.F., Zaman, I. and Lim, H.Q. (2019) 'Factors and barriers influencing lean production system adoption in manufacturing industries', *International Journal of Supply Chain Management*, 8(2), pp. 939-946. Available at:

https://core.ac.uk/download/pdf/230753147.pdf (Accessed: 23 July 2025).

Charron, R., Harrington, H.J., Voehl, F. and Wiggin, H. (2015) *The lean management systems book*. Florida: CRC Press, pp. 63-68.

Chen, L. and Meng, B. (2010) 'The application of value stream mapping based lean production system', *International Journal of Business and Management*, 5(6), pp. 203-209. Available at: https://pdfs.semanticscholar.org/4ea8/b128f19d2da024019653eb4aef3691eeaf1d.pdf (Accessed: 24 July 2025).

Chen, P.K., Fortuny-Santos, J., Lujan, I. and Ruiz-de-Arbulo-López, P. (2019) 'Sustainable manufacturing: exploring antecedents and influence of total productive maintenance and lean manufacturing', *Advances in Mechanical Engineering*, 11(11), [no pagination]. Available at: https://doi.org/10.1177/1687814019889736

Chen, T., Li, M. and Bae, J. (2024) 'Recent advances in lithium iron phosphate battery technology: a comprehensive review', *Batteries*, *10*(12), pp. 1-36. Available at: https://doi.org/10.3390/batteries10120424

Cherrafi, A., Elfezazi, S., Chiarini, A., Mokhlis, A. and Benhida, K. (2016) 'The integration of lean manufacturing, Six Sigma and sustainability: a literature review and future research directions for developing a specific model', *Journal of Cleaner Production*, 139(December), pp. 828-846. Available at: https://doi.org/10.1016/j.jclepro.2016.08.101

Cherrafi, A., Elfezazi, S., Garza-Reyes, J.A., Benhida, K. and Mokhlis, A. (2017) 'Barriers in green lean implementation: a combined systematic literature review and interpretive structural modelling approach', *Production Planning and Control*, 28(10), pp. 829-842. Available at: https://doi.org/10.1080/09537287.2017.1324184

Chotaliya, M. and Mehta, B.A. (2022) 'Kaizen techniques: a literature review', *International Journal of Current Research*, 14(1), pp. 20325-20329. Available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4677097 (Accessed: 22 July 2025).

Choudhary, S., Nayak, R., Dora, M., Mishra, N. and Ghadge, A. (2019) 'An integrated lean and green approach for improving sustainability performance: a case study of a packaging manufacturing SME in the U.K.', *Production Planning and Control*, 30(5-6), pp. 353-368. Available at: https://doi.org/10.1080/09537287.2018.1501811

Chowdhury, M.F. (2014) 'Interpretivism in aiding our understanding of the contemporary social world', *Open Journal of Philosophy*, 4, pp. 432-438. Available at: http://dx.doi.org/10.4236/ojpp.2014.43047

Ciarniene, R. and Vienazindiene, M. (2012) 'Lean manufacturing: theory and practice', *Economics and Management*, 17(2), pp. 726-732. Available at: https://doi.org/10.5755/j01.em.17.2.2205

Creswell, J.W. and Creswell, J.D. (2022) *Research design: qualitative, quantitative, and mixed methods approaches*. 6th edn. California: SAGE, pp. 1-32.

Croucher, S.M. and Cronn-Mills, D. (2015) *Understanding communication research methods: a theoretical and practical approach*. New York: Routledge, pp. 238-247.

Dainty, A. (2008) 'Methodological pluralism in construction management research', in Knight, A. and Ruddock, L. (eds) *Advanced research methods in the built environment*. Chichester, West Sussex: Wiley-Blackwell, pp. 1-12.

Damij, N. and Damij, T. (2024) 'An approach to optimizing Kanban Board workflow and shortening the project management plan', *IEEE Transactions on Engineering Management*, 71(November), pp. 13266-13273. Available at: https://doi.org/10.1109/TEM.2021.3120984

Dawadi, S., Shrestha, S. and Giri, R.A. (2021) 'Mixed-methods research: a discussion on its types, challenges, and criticisms', *Journal of Practical Studies in Education*, 2(2), 25-36. Available at: https://doi.org/10.46809/jpse.v2i2.20

Dennis, P. (2015) *Lean production simplified: a plain-language guide to the world's most powerful production system*. 3rd edn. Boca Raton, Florida: CRC Press, Taylor and Francis Group, pp. 18-34.

Deuse, J., Dombrowski, U., Nohring, F., Mazarov, J. and Dix, Y. (2020) 'Systematic combination of lean management with digitalization to improve production systems on the example of Jidoka 4.0', *International Journal of Engineering Business Management*, 12(January), [no pagination]. Available at: https://doi.org/10.1177/1847979020951351

Didden, J.B.H.C., Lefeber, E., Adan, I.J.B.F. and Panhuijzen, I.W.F. (2023) 'Genetic algorithm and decision support for assembly line balancing in the automotive industry', *International Journal of Production Research*, 61(10), pp. 3377-3395. Available at: https://doi.org/10.1080/00207543.2022.2081630

Dudek-Burlikowska, M. and Szewieczek, D. (2009) 'The Poka-Yoke method as an improving quality tool of operations in the process', *Journal of Achievements in Materials and Manufacturing Engineering*, 36(1), pp. 95-102. Available at: http://jamme.acmsse.h2.pl/papers_vol36_1/36112.pdf (Accessed: 23 July 2025).

Duque, D.F.M. and Capdavid, L.R. (2007) 'Lean manufacturing measurement: the relationship between lean activities and lean metrics', *Estudios Gerenciales*, 23(105), pp. 69-83. Available at:

e-ISSN: XXXX-XXXX
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http://www.scielo.org.co/pdf/eg/v23n105/v23n105a04.pdf (Accessed: 23 July 2025).

Elkhairi, A., Fedouaki, A. and Alami, S.E. (2019) 'Barriers and critical success factors for implementing lean manufacturing in SMEs', *IFAC-PapersOnLine*, 52(13), pp. 565-570. Available at: https://doi.org/10.1016/j.ifacol.2019.11.303

Esfandyari, A. and Osman, M.R. (2010) *Success and failure issues to lead lean manufacturing implementation*. Malaysia: University Putra Malaysia. Available at: https://www.researchgate.net/publication/266036539_Success_and_failure_issues_to_lead_lean_manufacturing_implementation (Accessed: 24 July 2025).

European Commission (2024) *Battery supply chain challenges*. Available at: https://rmis.jrc.ec.europa.eu/analysis-of-supply-chain-challenges-49b749 (Accessed: 22 July 2025).

Food and Rural Affairs (2024) 'UK statistics on waste', *Gov UK*, 26 September. Available at: https://www.gov.uk/government/statistics/uk-waste-data/uk-statistics-on-waste (Accessed: 24 July 2025).

Forghani, M.A. and Tavasoli, A. (2017) 'Investigating the relationship between knowledge management dimensions and organizational performance in lean manufacturing', *International Journal of Management, Accounting and Economics*, 4(3), pp. 218-225. Available at: https://web.p.ebscohost.com/ehost/pdfviewer/pdfviewer?vid=1&sid=c86dd4fb-08bb-4b88-a598-f27f3e098fdc%40redis (Accessed: 24 July 2025).

Franke, T.M., Ho, T. and Christie, C.A. (2012) 'The Chi-square test: often used and more often misinterpreted', *American Journal of Evaluation*, 33(3), PP. 448-458. Available at: https://doi.org/10.1177/1098214011426594

Geissdoerfer, M., Savaget, P., Bocken, N.M.P. and Hultink, E.J. (2017) 'The circular economy: a new sustainability paradigm?', *Journal of Cleaner Production*, 143(February), pp. 757-768. Available at: https://doi.org/10.1016/j.jclepro.2016.12.048

Gera, S., Chaukiyal, A., Rani, N. and Gambhir, S. (2025) 'Sustainability as strategy: the competitive edge for the net-zero economy', *International Journal of Environmental Sciences*, 11(14s), pp. 921-928. Available at: https://doi.org/10.64252/tgspq879

Geraldo dos Santos, Z., Vieira, L. and Balbinotti, G. (2015) 'Lean manufacturing and ergonomic working conditions in the automotive industry', *Procedia Manufacturing*, 3, pp. 5947-5954. Available at: https://doi.org/10.1016/j.promfg.2015.07.687

e-ISSN: XXXX-XXXX
Vol. I | Issue I |
June, 2026

GOV UK (2023) *Government sets out path to zero emission vehicles by 2035*. Available at: https://www.gov.uk/government/news/government-sets-out-path-to-zero-emission-vehicles-by-2035 (Accessed: 02 July 2025).

Govindan, K., Soleimani, H. and Kannan, D. (2015) 'Reverse logistics and closed-loop supply chain: a comprehensive review to explore the future', *European Journal of Operational Research*, 240(3), pp. 603-626. Available at: https://doi.org/10.1016/j.ejor.2014.07.012

Guariente, P., Antoniolli. I., Ferreira, L.P., Pereira, T. and Silva, F.J.G. (2017) 'Implementing autonomous maintenance in an automotive components manufacturer', *Procedia Manufacturing*, 13, pp. 1128-1134. Available at: https://doi.org/10.1016/j.promfg.2017.09.174

Gupta, S. and Jain, S.K. (2013) 'A literature review of lean manufacturing', *International Journal of Management Science and Engineering Management*, 8(4), pp. 241-249. Available at: https://doi.org/10.1080/17509653.2013.825074

Hafizuddin, M.M., Nazif, N.K.A., Needza, Y.M. and Nadiah, D.A. (2012) 'A study on line balancing in assembly line at automotive component manufacturer', *Proceedings of the 2012 International Conference on Industrial Engineering and Operations Management*, Istanbul, Turkey, 3-6 July. Available at: https://ieomsociety.org/ieom2012/pdfs/387.pdf (Accessed: 22 July 2025).

Hallgren, M. and Olhager, J. (2009) 'Lean and agile manufacturing: external and internal drivers and performance outcomes', *International Journal of Operations and Production Management*, 29(10), pp. 976-999. Available at: https://doi.org/10.1108/01443570910993456

Hallioui, A., Herrou, B., Katina, P.F., Santos, R.S., Egbue, O., Jasiulewicz-Kaczmarek, M., Soares, J.M. and Marques, P.C. (2023) 'A review of sustainable total productive maintenance (STPM)', *Sustainability*, 15(16), pp. 1-30. Available at: https://doi.org/10.3390/su151612362

Haque, B. and James-Moore, M. (2004) 'Applying lean thinking to new product introduction', *Journal of Engineering Design*, 15(1), pp. 1-31. Available at: https://doi.org/10.1080/0954482031000150125

Hayes, A. (2024) 'Chi-Square (χ2) Statistic: what it is, examples, how and when to use the test', *Investopedia*, 30 July. Available at: https://www.investopedia.com/terms/c/chi-square-statistic.asp (Accessed: 29 July 2025).

Hicks, B.J. (2007) 'Lean information management: understanding and eliminating waste', *International Journal of Information Management*, 27(4), pp. 233-249. Available at: https://doi.org/10.1016/j.ijinfomgt.2006.12.001

Hill, C. (2022) *International business: competing in the global marketplace*. 14th edn. New York: McGraw Hill, pp. 6-25.

Htun, A., Maw, T.T. and Khaing, C.C. (2019) 'Lean manufacturing, just in time and kanban of Toyota Production System (TPS)', *International Journal of Scientific Engineering and Technology Research*, 8, pp. 469-474. Available at: https://ijsetr.com/uploads/165423IJSETR17537-99.pdf (Accessed: 24 July 2025).

Jamil, M. and Razali, N.M. (2015) 'Simulation of assembly line balancing in automotive component manufacturing' (from the 2nd International Manufacturing Engineering Conference and 3rd Asia-Pacific Conference on Manufacturing Systems, Kuala Lumpur, Malaysia, 12-14 November), *IOP Conference Series: Materials Science and Engineering*, 114, pp. 1-8. Available at: https://doi.org/10.1088/1757-899X/114/1/012049

Jha, P.S. and Khan, M.S. (2017) 'An experimental study on the automotive production line using assembly line balancing techniques', *International Journal of Mechanical Engineering and Technology*, 8(3), pp. 22–33. Available at: https://iaeme.com/MasterAdmin/Journal_uploads/IJMET/VOLUME_8_ISSUE_3/IJMET_08_03_003.pdf (Accessed: 22 July 2025).

Ju, F., Li, J., Xiao, G., Arines, J. and Deng, W. (2015) 'Modeling, analysis, and improvement of integrated productivity and quality system in battery manufacturing', *IIE Transactions*, 47(12), pp. 1313-1328. Available at: https://doi.org/10.1080/0740817X.2015.1005777

Kafuku, J.M. (2019) 'Factors for effective Implementation of lean manufacturing practice in selected industries in Tanzania', *Procedia Manufacturing*, 33, pp. 351-358. Available at: https://doi.org/10.1016/j.promfg.2019.04.043

Kalsoom, T., Ahmed, S., Rafi-ul-Shan, P.M., Azmat, M., Akhtar, P., Pervez, Z., Imran, M.A. and Ur-Rehman, M. (2021) ‘Impact of IoT on manufacturing Industry 4.0: a new triangular systematic review’, *Sustainability 2021*, 13, pp. 1-22. Available at: https://doi.org/10.3390/su132212506

Kaushik, M. and Mathur, B. (2014) 'Data Analysis of Students Marks with Descriptive Statistics', *International Journal on Recent and Innovation Trends in Computing and Communication*, 2(5), pp. 118-1190. Available at: https://doi.org/10.17762/ijritcc.v2i5.3136

Khan, M.R., Islam, M.T., Islam, K.S. and Hossain, A. (2024) 'Closing the productivity gap in electric vehicles manufacturing: challenges and solutions', *Innovatech Engineering Journal*, 1(1), pp. 223-243. Available at: https://dx.doi.org/10.2139/ssrn.5068124

Kolberg, D., Knobloch, J. and Zuhlke, D. (2017) 'Towards a lean automation interface for workstations', *International Journal of Production Research*, 55(10), pp. 2845-2856. Available at: https://doi.org/10.1080/00207543.2016.1223384

Kumar, N., Hasan, S.S., Srivastava, K., Akhtar, R., Yadav, R.K. and Choubey, V.K. (2022) 'Lean manufacturing techniques and its implementation: a review', *Materialstoday: Proceedings*, 64(3), pp. 1188-1192. Available at: https://doi.org/10.1016/j.matpr.2022.03.481

Kumar, S. (2024) 'Inductive and deductive approaches to qualitative research', *International Journal of Multidisciplinary Educational Research*, 13(1), pp. 58-63. Available at: https://ijmer.s3.amazonaws.com/pdf/volume13/volume13-issue1(4)/9.pdf (Accessed: 28 July 2025).

Kumar, V., Sezersan, I., Garza-Reyes, J.A., Gonzalez, D.R.S and Al-Shboul, M.A. (2019) 'Circular economy in the manufacturing sector: benefits, opportunities and barriers', *Management Position*, 57(4), pp. 1067-1086. Available at: https://doi.org/10.1108/MD-09-2018-1070

Li, Z., Liang, F. and Cheng, M. (2021) 'Research on the impact of high-end EV sales business model on brand competitiveness', *Sustainability*, *13*(24), pp. 1-20. Available at: https://doi.org/10.3390/su132414045

Lu, Y. and Zhu, T. (2024) 'Status and prospects of lithium iron phosphate manufacturing in the lithium battery industry', *MRS Communications*, 14(September), pp. 888-899. Available at: https://doi.org/10.1557/s43579-024-00644-2

Manos, A. (2007) 'The benefits of Kaizen and Kaizen events', *Quality Progress*, 40(2), pp. 47-48. Available at: https://www.proquest.com/docview/214768622?pq-origsite=gscholar&fromopenview=true&sourcetype=Magazines (Accessed: 23 July 2025).

Manuguerra, L., Cappelletti, F., Rossi, M. and Germani, M. (2023) 'Design of electric vehicles for Industry 4.0: the case of an Autonomous Mobile Robot', *Procedia CIRP*, 120, pp. 980-985. Available at: https://doi.org/10.1016/j.procir.2023.09.111

Marinelli, M., Deshmukh, A.A., Janardhanan, M. and Nielsen, I. (2021) 'Lean manufacturing and Industry 4.0 combinative application: practices and perceived benefits', *IFAC-PapersOnLine*, 54(1), pp. 288-293. Available at: https://doi.org/10.1016/j.ifacol.2021.08.034

Marodin, G.A. and Saurin, T.A. (2015) 'Managing barriers to lean production implementation: context matters', *International Journal of Production Research*, 53(13), pp. 3947-3962. Available at: https://doi.org/10.1080/00207543.2014.980454

McKie, M.G., Evans, A.N. and Jones, R. (2024) 'Improving lean engagement through utilising improved communication, recognition and digitalisation during the COVID-19 Pandemic in JLR's Powertrain machining facility', *FME Transactions*, 52(1), pp. 136-146. Available at: https://doi.org/10.5937/fme2401136M

McKim, C.A. (2017) 'The value of mixed methods research', *Journal of Mixed Methods Research*, 11(2), pp. 202-222. Available at: https://doi.org/10.1177/1558689815607096

McKone, K.E., Schroeder, R.G. and Cua, K.O. (1999) 'Total productive maintenance: a contextual view' *Journal of Operations Management*, 17(2), pp. 123-144. Available at: https://doi.org/10.1016/S0272-6963(98)00039-4

Melnikovas, A. (2018) 'Towards an explicit research methodology: adapting research onion model for futures studies', *Journal of Futures Studies*, 23(2), pp. 29-44. Available at: https://doi.org/10.6531/JFS.201812_23(2).0003

Melton, T. (2005) 'The benefits of lean manufacturing: what lean thinking has to offer the process industries', *Chemical Engineering Research and Design*, 83(6), pp. 662-673. Available at: https://doi.org/10.1205/cherd.04351

Mohanty, R.P., Yadav, O.P. and Jain, R. (2007) 'Implementation of lean manufacturing principles in auto industry', *2007 International Conferences on India in the emerging global order*, Bhubaneswar, India, 29-21 January. Available at: https://www.researchgate.net/publication/228356063_Implementation_of_lean_manufacturing_principles_in_auto_industry?enrichId=rgreq-f755ce04e4ec974a35766bf5bc74887a-XXX&enrichSource=Y292ZXJQYWdlOzIyODM1NjA2MztBUzoxMjY0OTE1NzI1NzYyNTZAMTQwNzE2OTM0OTA2Mw%3D%3D&el=1_x_3&_esc=publicationCoverPdf (Accessed: 02 July 2025).

Morrison, J. (2023) *The global business environment: sustainability in the balance*. 6th edn. UK: Bloomsbury Academic, pp. 50-88.

Mostafa, S., Dumrak, J. and Soltan, H. (2013) 'A framework for lean manufacturing implementation', *Production and Manufacturing Research*, 1(1), pp. 44-64. Available at: https://doi.org/10.1080/21693277.2013.862159

Mukhopadhyay, S. and Gupta, R.K. (2014) 'Survey of qualitative research methodology in strategy research and implication for Indian researchers', *Vision*, 18(2), pp. 109-123. Available at: https://doi.org/10.1177/0972262914528437

Mwita, K.M. (2025) 'Understanding research philosophies and designs: a guide for early-career researchers', *Eminent Journal of Social Sciences*, 1(1), pp. 43-52. Available at: https://doi.org/10.70582/m1ne6430

Naeemah A.J. and Wong, K.Y. (2022) 'Positive impacts of lean manufacturing tools on sustainability aspects: a systematic review', *Journal of Industrial and Production Engineering*, 39(7), pp. 552-571. Available at: https://doi.org/10.1080/21681015.2022.2041742

Nallusamy, S. and Majumdar, G. (2017) 'Enhancement of overall equipment effectiveness using total productive maintenance in a manufacturing industry', *International Journal of Performability Engineering*, 13(2), pp. 173-188. Available at: https://doi.org/10.23940/ijpe.17.02.p7.173188

Niri, A.J. Poelzer, G.A., Zhang, S.E., Rosenkranz, J., Pettersson, M. and Ghorbani, Y. (2024) 'Sustainability challenges throughout the electric vehicle battery value chain', *Renewable and Sustainable Energy Reviews*, 191(March), pp. 1-15. Available at: https://doi.org/10.1016/j.rser.2023.114176

Nordin, N., Deros, B.M. and Wahab, D.A. (2010) 'A survey in lean manufacturing implementation in Malaysian automotive industry', *International Journal of Innovation, Management and Technology*, 1(4), pp. 374-380. Available at: https://www.ijimt.org/papers/68-M457.pdf (Accessed: 02 July 2025).

Oloke, D. and Abdallah, N. (2025) 'The impact of disruptive events on built environment degree apprenticeship delivery - a case study of COVID-19', *International Journal of Building Pathology and Adaptation*, 43(5), pp. 1197-1215. Available at: https://doi.org/10.1108/IJBPA-09-2022-0147

Omotayo, T. and Kulatunga, U. (2015) 'The research methodology for the development of a kaizen costing framework suitable for indigenous construction firms in Lagos, Nigeria', *Association of Researchers in Construction Management (ARCOM) Doctoral workshop*, Dublin, Ireland, 10 April. Available at: http://dx.doi.org/10.13140/RG.2.1.3395.1600

Othman, A.A., Sundram, VPK., Sayuti, N.M. and Bahrin, A.S. (2016) 'The relationship between supply chain integration, just-in-time and logistics performance: a supplier's perspective on the automotive industry in Malaysia', *International Journal of Supply Chain Management*, 5(1), pp. 44-51. Available at: https://www.researchgate.net/publication/303755024_The_relationship_between_supply_chain_integration_just-in-time_and_logistics_performance_A_supplier's_perspective_on_the_automotive_industry_in_Malaysia (Accessed: 24 July 2025).

Oye, E. and Anthony, M. (2025) *Leveraging lean manufacturing as a framework for agile innovation in electric vehicle production*. Available at: https://www.researchgate.net/publication/389673686_Leveraging_Lean_Manufacturing_as_a_Framework_for_Agile_Innovation_in_Electric_Vehicle_Production (Accessed: 21 July 2025).

Pacaiova, H. and Izarikova, G. (2019) 'Base principles and practices for implementation of total productive maintenance in automotive industry', *Quality Innovation Prosperity*, 23(1), pp. 45-59. Available at: https://doi.org/10.12776/qip.v23i1.1203

Palange, A. and Dhatrak, P. (2021) 'Lean manufacturing a vital tool to enhance productivity in manufacturing', *Materialstoday: Proceedings*, 46(1), pp. 729-736. Available at: https://doi.org/10.1016/j.matpr.2020.12.193

Patel, B.S., Sambasivan, M., Panimalar, R. and Krishna, R.H. (2022) 'A relational analysis of drivers and barriers of lean manufacturing', *The TQM Journal*, 34(5), pp. 845-876. Available at: https://doi.org/10.1108/TQM-12-2020-0296

Polonara, M., Romagnoli, A., Biancini, G. and Carbonari, L. (2024) 'Introduction of collaborative robotics in the production of automotive parts: a case study', *Machines*, *12*(3), pp. 1-11. Available at: https://doi.org/10.3390/machines12030196

Prabowo, H.A. and Adesta, E.Y.T. (2019) 'A study of total productive maintenance (TPM) and lean manufacturing tools and their impact on manufacturing performance', *International Journal of Recent Technology and Engineering*, 7(6S), pp. 39-43. Available at: https://www.ijrte.org/wp-content/uploads/papers/v7i6s/F02110376S19.pdf (Accessed: 22 July 2025).

Prakash, D. and Kumar, C.T.S. (2011) 'Implementation of lean manufacturing principles in auto industry', *Industrial Engineering Letters*, 1(1), pp. 56-60. Available at: https://core.ac.uk/download/pdf/234684962.pdf (Accessed: 02 July 2025).

Prayuda, R.Z. (2020) 'Continuous improvement through Kaizen in an automotive industry', *Journal of Industrial Engineering and Management Research*, 1(1), pp. 37-42. Available at: https://doi.org/10.7777/jiemar.v1i1.24

Qamar, A., Hall, M.A, Chicksand, D. and Collinson, S. (2020) 'Quality and flexibility performance trade-offs between lean and agile manufacturing firms in the automotive industry', *Production Planning and Control: The Management of Operations*, 31(9), pp. 723-738. Available at: https://doi.org/10.1080/09537287.2019.1681534

Quan, J., Zhao, S., Song, D., Wang, T., He, W. and Li, G. (2022) 'Comparative life cycle assessment of LFP and NCM batteries including the secondary use and different recycling technologies', *Science of the Total Environment*, 819(May), pp. 1-11. Available at: https://doi.org/10.1016/j.scitotenv.2022.153105

Rajak, S., Kumar, P., Modi, A., Swarnakar, V., Antony, J. and Ony, M. (2025) 'An assessment of barriers to integrate lean six sigma and industry 4.0 in manufacturing environment: case based approach', *International Journal of Computer Integrated Manufacturing*, 38(3), pp. 386-407. Available at: https://doi.org/10.1080/0951192X.2024.2335969

Renna, P., Magrion, L. and Zaffina, R. (2013) 'Dynamic card control strategy in pull manufacturing systems', *International Journal of Computer Integrated Manufacturing*, 26(9), pp. 881-894. Available at: https://doi.org/10.1080/0951192X.2013.799783

Rewers, P., Trojanowska J. and Chabowski P. (2016) 'Tools and methods of lean manufacturing- a literature review', P*roceedings of 7th International Technical Conference Technological Forum*, Czech Republic, 28-30 June. Available at: https://www.researchgate.net/publication/308171328_Tools_and_methods_of_Lean_Manufacturing_-_a_literature_review (Accessed: 22 July 2025)

Sahay, S. (2016) *Peeling Saunder's research onion*. Available at: https://www.researchgate.net/publication/309488459_Peeling_Saunder's_Research_Onion (Accessed: 28 July 2025).

Sahwan, M.A., Rahman, M.N.A. and Deros, B.M. (2012) 'Barriers to implement lean manufacturing in Malaysian automotive industry', *Jurnal Teknologi (Sciences and Engineering)*, 59(2), pp. 107-110. Available at: https://doi.org/10.11113/jt.v59.2571

Saunders, M.M.K., Lewis, P. and Thornhill, A. (2023) *Research methods for business students*. 9th edn. Harlow, UK: Pearson, pp. 128-184.

Shah, R. and Ward, P.T. (2003) 'Lean manufacturing: context, practice bundles, and performance', *Journal of Operations Management*, 21(2), pp. 129-149. Available at: https://doi.org/10.1016/S0272-6963(02)00108-0

Sharma, A. (2014) 'What is lean manufacturing?', *International Journal of Sciences*, 3(9), pp. 44-49. Available at: https://www.ijsciences.com/pub/pdf/V320140916.pdf (Accessed: 17 June 2025).

Sharma, R., Nagar, S. and Agrawal, P.K. (2013) 'Lean manufacturing: concepts and application', *National Symposium on Cleaner Production Technologies and Strategies*, GLA University and IIPE CHAPTER University Polytechnic, Mathura, India, 25-26 October. Available at: https://www.researchgate.net/publication/303068003_LEAN_MANUFACTURING_CONCEPTS_AND_APPLICATION (Accessed: 17 June 2025).

Shekarian, E. (2020) 'A review of factors affecting closed-loop supply chain models', *Journal of Cleaner Production*, 253(April), pp. 1-24. Available at: https://doi.org/10.1016/j.jclepro.2019.119823

Shen, H., Wang, H., Li, M., Li, C., Zhang, Y., Li, Y., Yang, X., Feng, X., and Ouyang, M. (2023) 'Thermal runaway characteristics and gas composition analysis of lithium-ion batteries with different LFP and NCM cathode materials under inert atmosphere', *Electronics*, 12(7), pp. 1-21. Available at: https://doi.org/10.3390/electronics12071603

Shi, X. Pan, J., Wang, H. and Cai, H. (2019) 'Battery electric vehicles: what is the minimum range required?', *Energy*, 166(1), pp. 352-358. Available at: https://doi.org/10.1016/j.energy.2018.10.056

Shi, Y., Chen, X., Jiang, T. and Jin, Q. (2023) 'Social life cycle assessment of lithium iron phosphate battery production in China, Japan and South Korea based on external supply materials', *Sustainable Production and Consumption*, 35(January), pp. 525-538. Available at: https://doi.org/10.1016/j.spc.2022.11.021

Sim, K.L. and Rogers, J.W. (2009) 'Implementing lean production systems: barriers to change', *Management Research News*, 32(1), pp. 37-49. Available at: https://doi.org/10.1108/01409170910922014

Singh, C.D., Singh, R., Mand, J.S. and Singh, S. (2013) 'Application of lean and JIT principles in supply chain management', *International Journal of Management Research and Business Strategy*, 2(1), pp. 85-98. Available at: https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=2e0e4773ef8ef20eb2e23d51181717dd7f9a92a3 (Accessed: 22 July 2025).

Singh, J. and Singh, H. (2009) 'Kaizen philosophy: a review of literature', *The Icfai University Journal of Operations Management*, 8(2), pp. 51-72. Available at: https://www.researchgate.net/profile/Harwinder-Singh-6/publication/268284725_5_1_Kaizen_Philosophy_A_Review_of_Literature_Kaizen_Philosophy_A_Review_of_Literature/links/54e16e510cf2953c22bb0263/5-1-Kaizen-Philosophy-A-Review-of-Literature-Kaizen-Philosophy-A-Review-of-Literature.pdf (Accessed: 22 July 2025).

Singh, B., Garg, S.K., Sharma, S.K. and Grewal, C. (2010) 'Lean implementation and its benefits to production industry', *International Journal of Lean Six Sigma*, 1(2), pp. 157-168. Available at: https://doi.org/10.1108/20401461011049520

Slack, N. and Brandon-Jones, A. (2019) *Operations Management*. 9th edn. Harlow, UK: Pearson, pp. 341-530.

Slack, N., Brandon-Jones, A. and Burgess, N. (2022) *Operations management*. 10th edn. Harlow, UK: Pearson, pp. 190-443.

Soori, M., Arezoo, B. and Dastres, R. (2023) 'Internet of things for smart factories in industry 4.0, a review', *Internet of Things and Cyber-Physical Systems*, 3, pp. 192-204. Available at: https://doi.org/10.1016/j.iotcps.2023.04.006

Souza, G.C. (2013) 'Closed-loop supply chains: a critical review, and future research', *Decision Sciences*, 44(1), pp. 7-38. Available at: https://doi.org/10.1111%2Fj.1540-5915.2012.00394.x

Suárez-Barraza, M.F., Ramis-Pujol, J. and Kerbache, L. (2011) 'Thoughts on Kaizen and its evolution: three different perspectives and guiding principles', *International Journal of Lean Six Sigma*, 2(4), pp. 288-308. Available at: https://doi.org/10.1108/20401461111189407

Sundar, R., Balaji, A.N. and Kumar, S.R.M. (2014) 'A review of lean manufacturing implementation techniques', *Procedia Engineering*, 97, pp. 1875-1885. Available at: https://doi.org/10.1016/j.proeng.2014.12.341

Swarnakar, V. (2021) 'Assessment of Critical Failure Factors for Implementing Lean Six Sigma in Manufacturing Industry: A case study', *International Journal of Industrial Engineering and Operations Management*, 3(1), pp. 16-32. Available at: https://doi.org/10.46254/j.ieom.20210102

Taherdoost, H. (2022) 'What are different research approaches? Comprehensive review of qualitative, quantitative, and mixed method research, their applications, types and limitations', *Journal of Management Science and Engineering Research*, 5(1), pp. 53-63. Available at: https://doi.org/10.30564/jmser.v5i1.4538

Thangarajoo, Y. and Smith, A. (2015) 'Lean thinking: an overview', *Industrial Engineering and Management*, 4(2), pp. 1-5. Available at: https://www.hilarispublisher.com/open-access/lean-thinking-an-overview-2169-0316-1000159.pdf (Accessed: 22 July 2025).

The Department for Transport, Office for Zero Emission Vehicles, and Browne, A. (2024) *Pathway for zero emission vehicle transition by 2035 becomes law*. Available at: https://www.gov.uk/government/news/pathway-for-zero-emission-vehicle-transition-by-2035-becomes-law (Accessed: 22 July 2025).

Thomas, D.R. (2006) 'A general inductive approach for analyzing qualitative evaluation data', *American Journal of Evaluation*, 27(2), pp. 237-246. Available at: https://doi.org/10.1177/1098214005283748

Tortorella, G., Sawhney, R., Jurburg, D., Carisio de Paula, I., Tlapa, D. and Thurer, M. (2021) 'Towards the proposition of a lean automation framework: integrating Industry 4.0 into lean production', *Journal of Manufacturing Technology Management*, 32(3), pp. 593-620. Available at: https://doi.org/10.1108/JMTM-01-2019-0032

Tortorella, G.L., Fettermann, D., Fogliatto, F.S., Kumar, M. and Jurburg, D. (2021) 'Analysing the influence of organisational culture and leadership styles on the implementation of lean manufacturing', *Production Planning and Control*, 32(15), pp. 1282-1294. Available at: https://doi.org/10.1080/09537287.2020.1799255

Ullah, I., Zheng, J., Iqbal, M., Ahmad, M., Jamal, A. and Severino, A. (2025) 'Interpretive structural model for influential factors in electric vehicle charging station location', *Energy*, 325(June), pp. 1-13. Available at: https://doi.org/10.1016/j.energy.2025.136154

Varela, L., Araujo, A., Avila, P., Castro, H. and Putnik, G. (2019) 'Evaluation of the relation between lean manufacturing, Industry 4.0, and sustainability', *Sustainability*, 11(5), pp. 1-19. Available at: https://doi.org/10.3390/su11051439

Vidgen, B. and Yasseri, T. (2016) 'P-values: misunderstood and misused', *Frontiers in Physics*, 4(6), pp. 1-5. Available at: http://dx.doi.org/10.3389/fphy.2016.00006

Wesselkamper, J., Dahrendorf, L., Mauler, L., Lux, S. and von Delft, S. (2024) 'Towards circular battery supply chains: strategies to reduce material demand and the impact on mining and recycling', *Resources Policy*. 95(August), pp. 1-12. Available at: https://doi.org/10.1016/j.resourpol.2024.105160

Wolniak, R. (2024) 'The usage of poka-yoke in Industry 4.0 conditions', *Scientific Papers of Silesian University of Technology Organization and Management Series*, (191), pp. 613-628. Available at: http://dx.doi.org/10.29119/1641-3466.2024.191.39

Xiang, Z.T. and Chin, J.F. (2021) 'Implementing total productive maintenance in a manufacturing small or medium-sized enterprise, *Journal of Industrial Engineering and Management*, 14(2), pp. 152-175. Available at: https://doi.org/10.3926/jiem.3286

Yuwono, M.A. and Rachmawati, D. (2023) 'Combined methods. Can this solve the differences between deductive and inductive methods in qualitative research?', *Moroccan Journal of Quantitative and Qualitative Research*, 5(3), [no pagination]. Available at: https://doi.org/10.48379/IMIST.PRSM/mjqr-v5i3.45541

Zarbo, R.J. (2012) 'Creating and sustaining a lean culture of continuous process improvement', *American Journal of Clinical Pathology*, 138(3), pp. 321-326. Available at: https://doi.org/10.1309/AJCP2QY1XGKTSNQF

Zarrar, A., Rasool, M.H., Raza, S.M.M. and Rasheed, A. (2021) 'IoT-enabled lean manufacturing: Use of IoT as a support tool for lean manufacturing', *2021 International Conference on Artificial Intelligence of Things*, Nicosia, Turkey, 3-4 September. Available at: https://doi.org/10.1109/ICAIoT53762.2021.00010

Zhang, L., Narkhede, B.E. and Chaple, A.P. (2017) 'Evaluating lean manufacturing barriers: an interpretive process', *Journal of Manufacturing Technology Management*, 28(8), pp. 1086-1114. Available at: https://doi.org/10.1108/JMTM-04-2017-0071

Zhao, T., Choi, Y., Wu, C., Zhang, Z., Wang, C., Liu, D., Xu, W., Huang, H., Huo, X., Zhao, W., Zhao, Z. and Li, W. (2024) 'A review on direct regeneration of spent lithium iron phosphate: from waste to wealth', *Science of the Total Environment*, 957(December), pp. 1-16. Available at: https://doi.org/10.1016/j.scitotenv.2024.177748

Zope, A., Swami, R.K. and Patil, A. (2023) 'Lean six sigma barriers with potential solutions in electric vehicles assembly: a review', *Proceedings on Engineering Sciences*, 5(3), pp. 375-382. Available at: https://doi.org/10.24874/PES05.03.002