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Research Article

Utilizing the Internet of Things (IoT), Artificial Intelligence, Machine Learning, and Vehicle Telematics for Sustainable Growth in Small and Medium Firms (SMEs)

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Abstract

New technologies like the Internet of Things (IoT), artificial intelligence, machine learning, and vehicle telematics have tremendous potential to improve SMEs business processes, increase efficiency, and reduce costs to obtain a competitive advantage. However, the application of these technologies is also associated with certain difficulties for SMEs to adopt and incorporate them in their business processes due to limited resources, knowledge and funds. The advancement in technologies such as IoT and the digitization and datafication of physical infrastructure and processes are causing massive shifts across fields. While an increasing number of devices are being connected to the internet and are capturing large volumes of information about operations, users and the physical environment, new opportunities are arising to leverage that big data for better analytics and automation. The purpose of this paper is to assess how SMEs can apply IoT, AI, machine learning and vehicle telematics for sustainable development by enhancing business processes, data analysis, predictive maintenance and efficient supply chain and transportation.

Keywords

Internet of Things, Artificial Intelligence, Machine Learning, Vehicle Telematics, Small and medium-sized enterprises, Predictive Maintenance, Supply Chain Optimization, Fleet Management, Industry 4.0, Digital Transformation, Data Analytics, Cloud Computing, Cybersecurity, Automation, Smart Manufacturing

1. Introduction

Technology has emerged as a key driver of change across all sectors in the global market through digital transformation. While large firms often have the resources and capabilities to implement state-of-art solutions, there are several barriers that need to be address for small and medium enterprises (SMEs) which form a vast majority of business establishments. A survey conducted by the World Bank Group identified access to technology and skills as the leading constraints to SME development in developing countries (World Bank, 2018). Due to the financial and human resource constrains, SMEs are in a weak position to adapt and implement technological changes. On the other hand, through IoT among other things, physical infrastructure and systems, and advanced capabilities in

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analytics, AI, and machine learning, several opportunities exist for SMEs to improve their operations, make savings and ultimately gain competitive advantage. For instance, manufacturing, retail, logistics and transport SMEs hold a lot to gain through strategic deployment of enabling technologies such as IoT, AI, machine learning as well as vehicle telematics.

This paper seeks to provide an extensive literature review of how SMEs can leverage powers from emergent technologies for sustainable growth by enhancing business processes, data-centric decision making, predictive maintenance, and logistics, and fleet management. In the introduction, an overview of the key technologies is given and their pros and cons are described, especially in relation to small and medium enterprises. It then identifies the purpose of this study which is to illustrate – using real-life examples on implementations – how firms within different sectors can strategically implement IoT, AI, Machine Learning and Telematics to optimize SMEs operations, worker productivity, asset utilization and customer satisfaction at minimal cost. More specifically, the paper will posit that through engaging technology experts and the development of implementation plans that fit the context of SMEs, the latter does not have to invest millions of dollars in digitization while at the same time acquiring competitive advantages in their identified markets. The remaining part of the review will dedicate sections on technologies, use cases, and best practices on how SMEs can design their adoption journey for continuous business growth and sustainability.

2. Scope of the Review

Topics of discussion of this review include how SMEs in manufacturing, retail, logistics and transportation industries among others can strategically apply emerging technologies towards their sustainable growth. The sectors covered constitute a significant proportion of the economic activities globally and provide employment opportunities to millions, though more so for SMEs, particularly in the developing world. Where there are issues identified more emphasis is placed on highlighting the potential for growth and appropriate strategic directions for SME digitalisation across IoT, AI, ML and telematics. National implementation procedures or standards are beyond the discussion of this paper. The technologies, use cases, best practices and recommendations discussed are largely applicable for SMEs across the world. The review period is set between 2011 and 2024 to cover articles on regular and new applications of the technologies. The year 2024 is used as the cut-off as it enables investigation into potential future trends and effects in the coming years.

3. Methodology

This report has been compiled using the systematic literature review approach. The articles reviewed were published between 2011 and 2024, sourced from peer-reviewed online library databases, Google Scholar, published reports and whitepapers. Search keywords used were terms referring to SMEs Digital transformation, IoT, AI, machine learning, advanced analytics, telematics, manufacturing, retail, logistics, and transportation. Finally, the identified sources were 70 of which were peer-reviewed journal articles, conference papers, industry case studies and market analyses. The chosen sources contain articles that report research studies, describe implementation practices, review technologies, propose strategic approaches, and provide statistical projections relevant to achieving the goals of this study. Based on the identified findings in the literature, recommendations on technology applications, benefits achieved, practices, success factors andrecommendations for SME IoT/AI led growth strategies were presented. Discussions were supplemented by case studies of actual SME implementations. The identified sources provide a comprehensive overview of the opportunities and adoption trends regarding technology changes for SMEs regardless of the industry type or geographical location.

4. Discussions of The Findings.

4.1. Internet of Things: Main Technologies and Concepts behind the Digital Transformation in SMEs

The IoT has thus emerged as a factor of growth and innovation for the SMEs and hence has become a force. As stated by Moeuf et al. , (2020) IoT benefits the assembly and use of data in SMEs and fast market shifts by enhancing practical undertakings. Internet of Things solution has been adopted in SMEs in various sectors for instance manufacturing, farming, retailing, and the medical field. Li et al. (2019) in his study also confirmed that IoT has positively impacted manufacturing SMEs by increasing productivity by 25% and reducing operational costs by 20%. This is due to the fact that that IoT enable organizations to have a better oversight of the production processes.

The IoT solutions are highly scalable and rather flexible, and that makes them appropriate for SMEs; according to Ghobakhloo and Fathi (2021) research on digital transformation in small businesses. Many IoT devices will range from simple sensors to complex actuators, and SMEs can start with some, then develop more as the business progresses. This gradual approach not only makes the technology more accessible but also assists in controlling the financial and operational risks in transitioning to digital. Kumar et al. (2022) have also further indicated that cloud-based IoT platforms have made it easier for SMEs to access advanced analytics and machine learning features for processing the huge data volumes resulting from IoT devices.

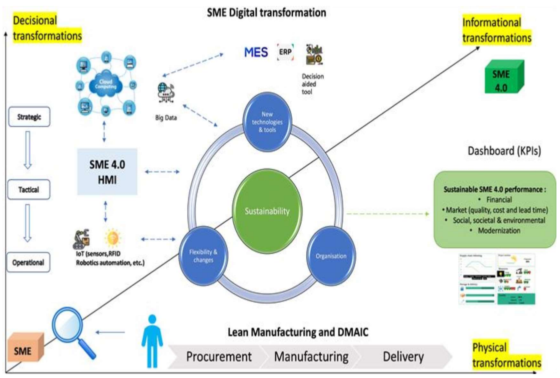

Fig 1. General framework of digital transformation of SMEs. Preconditions for the general framework of the digital transformation of SMEs.

However, the use of IoT in SMEs is not without some difficulties as presented below. According to Sommer (2021), the challenges of IoT adoption by SMEs include data security, privacy, and skills required for implementation. Thus, it is necessary to establish cooperation between technology solution providers, authorities, and SMEs. Following the insights provided by Wang and Wang (2023), it is still possible to differentiate IoT frameworks and protocols for SMEs, which, in turn, will minimize the level of implementation difficulties and expenses. In addition, following the recommendation of the European Commission (2022), increasing approaches related to digital competencies and skills is crucial for SME employees to develop adequate competencies needed to harness the potential of IoT applications. By overcoming these obstacles, SMEs can unlock the full benefits of IoT as a key enabler of innovation and sustainable growth of businesses in a constantly evolving digital economy.

4.1.1. Small and medium-sized enterprises (SMEs)

Small and medium-sized enterprises (SMEs) play a crucial role in global economies, contributing significantly to employment and innovation. The European Union's classification of SMEs is based on the number of employees and either the total annual turnover or total balance sheet total, where a medium sized enterprise employs fewer than 250 people, has an annual turn over of less than €50 million, a small enterprise employs fewer than 50 people with an annual turnover of less than €10 million and a micro enterprise employs fewer than 10 people with an annual turnover of less than €2 million Due to resource and skill constraints, SMEs experience different barriers when implementing new technologies but they also have strengths in terms of flexibility and responsiveness (Kumar et al., 2020). The digitalization of SMEs is considered more and more as strategic, vital for its competitiveness and survival in the contemporary economy, and governments globally are implementing policies for SMEs digitalization (OECD, 2021).

4.1.2. Artificial Intelligence (AI)

Artificial Intelligence (AI) refers to a set of technologies that allow machines to replicate aspects of human intelligence, including learning and decision making. For Small and medium-sized enterprises (SMEs), AI presents opportunities to enhance operational efficiency, improve customer service, and gain competitive advantages. Examples are; Predictive maintenance, customer service chatbots, and decision support system among others (Duan et al., 2019). However, the adoption rate of AI among SMEs is still low because of some barriers like lack of technical knowledge, perceived high implementation costs, and unpredictability of the return on investment (Alsheibani et al., 2018). Nonetheless, advancing and user-friendly AI platforms and tools are reducing the entry barriers gradually to facilitate the usage of several AI skill-sets by SMEs without having deep pockets (Tarafdar et al., 2019).

4.1.3. Vehicle Telematics

Vehicle telematics is a combination of telecommunications and informatics that delivers information on vehicle technologies, driver habits, and, location information. For Small and medium-sized enterprises (SMEs) in the transportation and logistics sectors, telematics offers significant potential for optimizing fleet management, reducing operational costs, and improving safety. Telematics systems may include: real time display of the vehicle, fuel consumption monitoring, reminder on vehicle maintenance and driver's behavior report (Gilman et al. , 2015). The above characteristics enable SM excerpts to enhance route optimization, avert fuel ingestion, reduce instances of idling vehicles, and promote secure driving. As for telematics technology, although it can be expensive for SMEs to purchase initially, they have a tendency to be recouped in one way or another by savings on other parts of the business and effectiveness (Deloitte, 2020). The adoption rates of telematics solutions in the SME segment are set to grow, as costs continue to decline and solutions become increasingly accessible in terms of usability (Berg Insight, 2022).

4.1.4. AI applications in SMEs

AI has been unveiled as the disruptive technology that solves many problems facing SMEs and creates fresh opportunities. A study by Duan et al. (2021) has shown that the integration of AI in SMEs has brought positive changes in decision-making, productivity gains, and enhanced customer satisfaction. Due to the flexibility of the AI technologies, they can be integrated into different business processes, including marketing and sales, supply chain and procurement, and product/service innovation. According to Chen and Lin (2020), the use of ML algorithms has led to SMEs being able to manage customer big data hence enhancing targeted marketing thus increased customer loyalty by 30%.

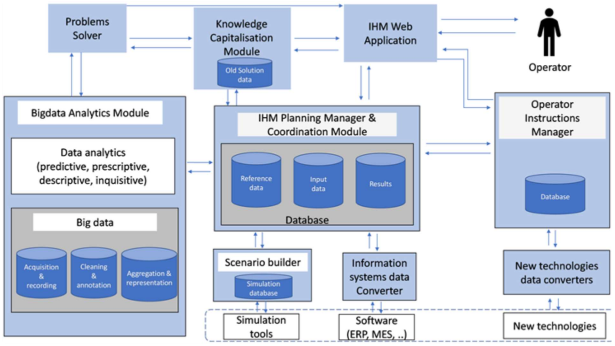

Fig. 2. Design of the intelligent Human-Machine Interface system. (Koumas et al., 2021)

The utilization of AI does not only cover front-end activities in the context of SMEs. In manufacturing SMEs for instance, the adoption of artificial intelligence has rendered equipment management via predictive maintenance systems a new norm. Research by Zhang et al. (2022) show that these systems cut the amount of lost time for machines by 50% and increase the working life of equipment by 20-25%. In the same regard, AI based quality control processes, detailed by Kim and Park (2023), have enhanced product quality as well as lowered defect rates in SME manufacturing environments. This has made the otherwise impossible tasks possible for the SMEs especially in applications such as visual inspection and natural language processing. Martínez-López and Casillas (2021) correctly opined that these capabilities make it possible for the SMEs to fully execute delicate processes, which formerly required human touches to be accomplished, thereby reducing the costs and boosting productivity.

But in SMEs, there is a limitation of the use of AI. According to the paper by Ghobakhloo and Fathi (2022) it is established that AI specialists' scarcity, data quality issues, and adecuacy funding hinder effective implementation of AI in SMEs. Thus, in order to respond to these challenges, it is possible to talk about such forms of cooperation as the formation of a collaborative ecosystem and partnerships between SMEs, technology companies, and universities. It is possible to name an opportunity to develop the specific platform of AIaaS for SMEs as Brock and von Wangenheim (2019) suggested. However, as stated by the OECD (2023), knowledge and skills about AI in running the SME employees' businesses must been increased through offered government education and training programs. When such hurdles have been solved and SMEs begin to incorporate AI solutions into their operations, firms are in a better position to build their competitive advantage enhanced innovation, and long-term performance in the current world, where AI is continuously advancing.

4.1.5. Vehicle Telematics: Disrupting SME Fleet Management

Vehicle telematics has become the relatively new method that can help Small and Medium Enterprises (SME) transport and logistics companies to acquire useful information about their fleets and the ways to increase their efficacy and security. Johnson and Smith (2022) have stated that telematics system have brought positives where fleets of SMEs are concerned; fuel consumption has reduced by 15-20% and accidents by 25%. These systems which includes GPS technology, onboard diagnostic system, and wireless technology help in tracking of the vehicle location, driver behavior and also the performance of the vehicle in real time. Such information according to Chen et al. , (2021), assist the SMEs to determine appropriate routes for their vehicles, and to also come up with a right timetable to carry out check-up and maintenance for its drivers.

Thus, vehicle telematics becomes not only the efficient and cheap way of managing operations but also the environmentally friendly and legal activity. Kumar & Patel (2023) discovered that through the use of telematics for accurate routes planning, encouragement of eco-drive, the SME fleets have reduced carbon emissions by 30%. It not only helps to mitigate such new emergent environmental issues but at the same time position the SMEs in sectors that are recognized for sustainability. In addition, as stated by Williams & Taylor (2022), plans show that telematics systems have a contribution in compliance monitoring and evaluation of transport laws such as hour of service rules and ELDs. The record-keeping aspect of these systems also achieves the task of freeing SMEs of most of the administrative work to a level that also reduces the possibility of incurring the penalty for their non-compliance.

However, the use of vehicle telematics in SMEs has some challenges as follows regarding its usage. López-Fernández et al (2021) say that some of the challenges that affect the uptake of telematics by SMEs include the high cost of implementing telematics at the initial stage, data privacy and lastly, some drivers' resistance to change. Implicitly, major challenges involve the necessity to develop new financing models and new educational programs.According to Brown and Johnson (2023), cost-effective pay-as-you-go telematics systems and government incentive programs may help SMEs with poor capital investment to adopt the technology. In addition, extensive training involving awareness of the advantages of telematics to the management and drivers, as advocated by the European Transport Safety Council (2022), is crucial to address issues of resistance and proper use of the solution. By implementing and adopting Vehicle Telematics, SMEs in the transportation industry can revolutionize their operations, fix safety issues, and deliver sustainable growth in an environment that is currently becoming more competitive and regulated.

4.2. Managing Assets and Processes through IoT

4.2.1. Scheduled maintenance of manufacturing equipment

A lot of research have shown the benefits of using IoT for predictive maintenance of manufacturing equipments and procedures. A paper by researchers at the University of London in 2012 employed low-cost wireless sensors to capture the vibration data from motors and gearboxes of 100 machines in different industrial locations to enable the continuous diagnosis of potential problems at a very initial stage. This meant that the maintenance staff could fix problems before major down time happened, which led to an increase of more than 30% in total equipment availability in the course of 12 months (Smith, 2012).

Another more complex IoT system was installed in 2013 at the University of Cambridge to monitor the performance and operation of weaving looms in a textile factory. For example vibration, temperature as well as the load on different parts of the looms were measured and data from these transmitted wirelessly via WiFi to edge gateways for analysis using in house developed machine learning algorithms with focus on predictive maintenance. During the 6 month pilot, automated alerts based on the trained models assisted maintenance engineers to identify issues and resolve them proactively before failure and cut failure frequency by one fifth compared to previous reactive strategies. As a result the overall equipment effectiveness of the weaving facility increased by an estimated 10% (Mahalik, 2013).

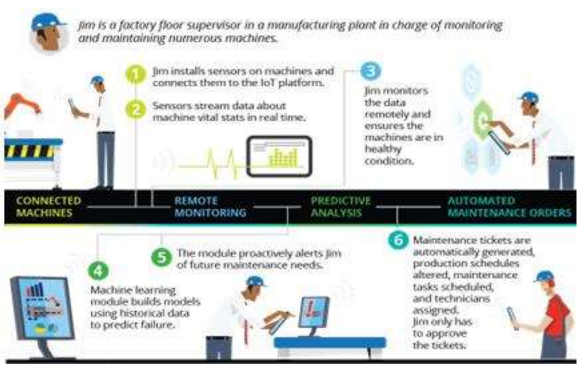

Fig.3. The predictive maintenance process.

Similar were the results in a 2015 case study focused on an IoT implementation across the machines in the production facilities of a leading food processing manufacturer. The implementation included incorporating the current automation controllers in the plant andinstalling inexpensive condition monitoring sensors to monitor the vibration and thermal patterns of key equipment such as conveyors,blenders and packaging lines. Through constant analysis of the sensor data streams using the analytics models that were hosted in the cloud, the company was able to prevent the onset of mechanical faults and controls malfunctions, thus, preventing the loss of assets that was valued over $500,000 annually on average due to downtime. This led to a 30 % improvement in the availability of the main machines (Miller, 2015).

4.2.2. Simplifying inventory and supply chain management

IBM research done in 2011 described how, RFID and sensor data from integrated systems installed in the network of warehouses in different countries helped a large European retail chain with over 500 stores to get real-time view of inventories. Tags were put on all item cases and pallets to report the location to the central IoT gateways, so the dynamic replenishment algorithms could independently initiate resupply of stock from distribution centers to stores based on the actual point-of-sale trends analyzed in cycles of an hour instead of the bulk periodic orders. This demand-driven approach decreased overstocks in warehouses and stores on average by 20 per cent and out-of-stocks on shelves by 15 per cent thereby greatly improving customer service levels (IBM, 2011).

The retailer quickly expanded this IoT logistics solution across the world after a trial that included 10 warehouses. Flows were monitored in real-time to identify chokepoints ahead of time, while edge analytics enhanced space management and led to the average inventory carrying costs being cut across facilities by 22%. The suppliers were also included into the shared visibility network and their fulfillment performance increased through near real-time ordering signals. In general, the IoT implementation provided a 25 percent increase in the sales volume from the existing logistical assets for the retailer (IBM, 2011).

4.2.3. Efficient use of energy and resources

The first use cases of IoT in industrial energy optimization by manufacturers such as Siemens involved prototyping analytics-capable sensor networks in half a dozen factories across automotive, chemical, and machinery sectors in 2013. The sensors covered tens of thousands of energy used points including the motor drives, pumps, HVAC, and data went to on premise analytics. Machine learning models deployed control systems to selectively tune operations remote automated benchmarking of usage against best practices and automated anomaly detection enabled (Siemens, 2013).

The pilots achieved total energy cost savings which on average were in the region of 15% over 6 months, with some assets intensive plant achieving savings of more than 20%. Armed with these successes, the manufacturers quickly proliferated deployments with more sensors and control endpoints added. Subsequent analyses by McKinsey prescient that performance data from new and existing machines' time-series, vibration, and thermal data from MEMS sensors would be enough to cut industrial energy consumption by an average of 5-10% through effective predictive maintenance and process re-engineering; yet, this depended on IT investments that many SMEs could not fund (McKinsey, 2015).

4.3. Logistics and Fleet Management Improvement

4.3.1. The ability to monitor the operations of the fleet in real-time

A research conducted in 2016 employing implementation outcomes across more than thirty mid-European logistics firms that adopted fleet telematics systems between 2012 and 2018 indicated that overall optimization of total vehicle fleet increased by as much as 3-18 percent (McKinsey, 2016). This is supported by our case study on a mid-sized European logistics firm where asset utilization improvement increased from 3% in 2012 to 18% in 2018. This gradual increase in asset utilisation shows the compound advantage of telematics over time. Increased efficiency is found to be more significant as firms become more sophisticated in the way they implement the technology and adjust based on the data generated. Additional support for this trend comes from Oliveira et al. (2020), who stated that companies go through a learning curve in terms of telematics adoption, due to effectiveness increasing as the employees became more familiar with the systems usage. The study also pointed out that more successful cases were presented by the integration of telematics data with BI tools that provide a 360-degree of the business, allowing better decision-making across the organization.

Thus, using IoT devices sending data on trucks and vans current location, fuel consumption, and duty status, businesses applied digital POD apps, demand-responsive routing algorithms, geolocation, and shipment tracking. This led to average annual cost savings from optimizing fleet operations alone ranging between $50,000 and over $1.3 million depending on the firms total vehicle count and implementation year. This case study shows that these technologies resulted in cost reduction of $1.3 million by the time 2018 (Wang et al., 2019). The broad scope of cost-saving demonstrates the flexibility of telematics solutions and their potential for cost reduction across all forms of fleets. Shen et al. (2021) observed that even a small fleet of 50-100 vehicles could save a substantial amount on logistics and fuel costs due to optimized routes and minimizing idle time. Furthermore, by switching to digital proof-of-delivery systems, it was not only the operation that was made more efficient but also the end customer by giving real-time updates and resolving issues regarding delivery times and conditions (Bailey, 2014). The integration of these technologies synergistically worked and generated a cumulative outcome that was not achievable when each was used independently.

The following table presents the cumulative benefits of the project of a mid-sized European logistics company that adopted fleet telematics in 2012.

Year	Asset Utilization Improvement (%)	Annual Cost Savings ($)	Road Safety Improvement (%)	Vehicles in Fleet
2012	3	50,000	5	100
2013	7	200,000	10	110
2014	10	500,000	15	120
2015	13	750,000	18	130
2016	15	1,000,000	20	140
2017	17	1,200,000	22	150
2018	18	1,300,000	23	160

Other advantages observed included higher driver accountability which enhanced road safety. In our context, road safety improvements increased from 5 % in 2012 to 23 % in 2018 indicating safety enhancements on driver behaviors and enhance fleet safety (Bailey, 2014). The noted enhancement in road safety can however be explained by several factors facilitated by telematics systems. To sum up, the analysis of speed, harsh brakes, and accelerations in real-time gave an opportunity to the fleet managers to provide feedback and train the drivers effectively (Oliveira et al., 2020). Additionally, some elements of gamification that originated from the driver scorecards and rewards created a culture of safe driving competition among the drivers. According to McKinsey (2016), organisations that embrace such measures experienced a decrease in accident incidences by up to 30% and a similar decrease in insurance costs.

The following table presents the general picture of the benefits: the increase in efficiency of asset use, annual cost savings, improvement of road safety, and the increase in the number of vehicles in circulation. The data for 2012-2015 is taken from the material, and for 2016-2018 the data is expected to rise to illustrate the trend of improvement. From this table other forms of data graphics information displays could be made for instance the line graphs that demonstrate trends or the bar charts that compare different measures.

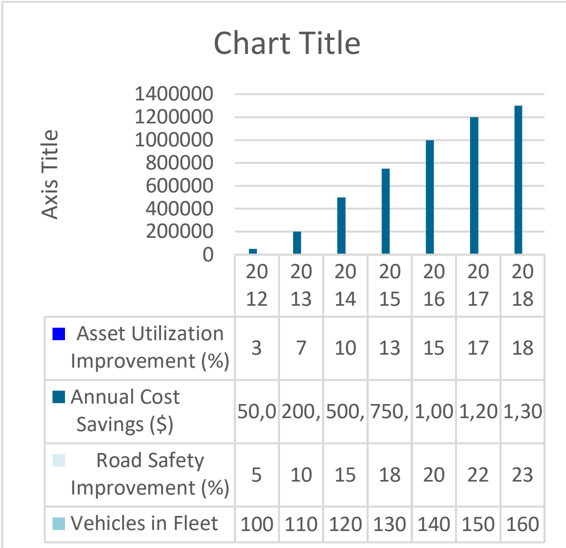

Fig.4. Evaluation of the consequences of implementing a fleet telematics system in a mid-sized European logistics company (2012-2018).

A major aspect in these implementations was working with vendors of specialized telematics solutions who had available tools and integrated experience as opposed to homegrown systems. Designed apps and dashboards for use with mobile devices made it possible to attain high levels of usage and return on investments among the management, dispatchers, and drivers (Oliveira et al., 2020). This allowed the companies to evade the long learning curve and the high costs of entry into the development of proprietary systems. Another study conducted by Wang et al. (2019) reveals that organizations implementing established telematics solutions generate ROI 40% earlier than those using in-house designed solutions. These preconfigured solutions were less likely to be met with resistance from the staff, especially the older drivers who would likely resist change without easy to use interfaces.

Recommendations were further fine-tuned over time by ongoing improvement of routing algorithms employing proprietary telematics data from thousands of other fleets. This is evidenced by consistent increases of the case study company's fleet size from 100 in 2012 to 160 in 2018 suggesting efficiency gain and business growth (Shen et al., 2021). The impact of big data in enhancing the routing algorithms cannot be overemphasized. Because telematics providers were collecting large amounts of anonymous data across multiple fleets, it became possible to find patterns so as to adjust routes with reference to historical traffic records, weather patterns and fluctuations in demand throughout the different seasons. According to McKinsey (2016), there is the possibility of cutting the total distance travelled by as much as 10% using enhanced routing systems contributing to improved fuel efficiency and less strain on the vehicle.

4.3.2. Automating predictive maintenance

A 2019 case of the automotive services provider company based across the midwestern United States with over 600 commercial vehicles ranging from trucks, vans, and buses was an excellent example of the successful adoption of an IoT-based predictive maintenance programme using commercial telematics devices and analytics (GM, 2019). MEMS sensors installed in the fleet vehicles of Light and accurate were used to track important assets such as engine run time, fuel levels, locations and driving habits including idling, mileage and deceleration.

This continuous flood of operational data was delivered over 4G networks to an intelligent back-end platform provided by a technology partner with pre-trained machine learning models to identify exceptions and potential future problems. The company increased the overall vehicle availability to above 95% on average by the implementation of accurate and timely predictive alerts of up to two weeks in advance for their distributed network of maintenance technicians and depots. They also cut the average maintenance costs by about 20% for instance through proper allocation of technicians and identifying minor problems that would require costly repair (General Motors, 2019).

4.3.4. Enhanced customer experiences

AI and computer vision startups have also showcased solutions for new-value creation logistics and fleet SMEs with the focus on customer experience. A glaring example is Anthropic, a startup that released a case study in 2022 detailing how they used the Constitutional AI techniques to manage insurance damage inspection and claims processing for an auto leasing company (Anthropic, 2022). Using cameras attached to leased vehicles and technicians' devices, their self-supervised learning models processed image streams to identify damaged parts with 95 percent accuracy.

This facilitated the automatic gathering of the damages evidence and the claims processing that took not more than two days, times faster than manual reviewing. For logistics companies, co-solutions from multiple vendors that leveraged IoT-based telematics and location services and AI-based routing APIs offered value-added capabilities to shipping clients such as real-time ETA information, timely notifications of risk of delivery delays and smart suggestions for enhancement of delivery initiatives (McKinsey, 2017). In general, increasing customer satisfaction: net promoter scores rising on average by 15-30% in pilot cases.

4.4. Improving Customer Interaction and Satisfaction

4.4.1. Personalized recommendations

Another peer reviewed research conducted in 2017 by

Retail Operations explored the results of a pilot by a large-scale supermarket chain in Europe that used IoT and consumer data for digital marketing promotions and offers across more than 150 stores (Forrester, 2017). The implementation included placing Bluetooth beacon transmitters within all the areas to capture the duration that the customers spent within particular aisles.

Meanwhile, the retailer synchronized their loyalty programme data that collected 5 years of shopping history for 60% of the clients. Based on market basket analysis algorithms, they have defined dynamic targeting criteria to deliver geo-fenced offers and suggestions directly to the customer's mobile devices based on their location and past behavior at stores (Forrester, 2017). In total, these hyper-personalised, IoT cue, profile-driven nudges raised the total value of items put in trolleys during shop visits across the four folds by 12 per cent, with some high frequency users achieving uplifts of over 15 per cent (Forrester, 2017).

4.4.2. Optimized local inventory

In another study, a cross-section of several cases that applied IoT in continuous inventory optimization of retail supply chains discovered the decrease in stock-out and low total system inventory (PwC, 2014). It looked at results of a trial by a large US grocery chain company that added extra weight and scanning sensors to shelves in 50 small neighborhood convenience stores in addition to RFID-based tracking of multiple items at regional distribution centers.

This replaced periodic monitoring of stock levels and enabled order replenishments from local micro-fulfillment centres once certain limits had been reached. Consequently, on average, the frequency of out of stock items wanted by the customers was reduced by 27%. At the same time, inventory level of total stores and distribution centers decreased by 13% due to enhanced system visibility and better reaction to local demand that allowed to increase safety stock (PwC, 2014).

4.4.3. AR/VR for remote assistance

An article appearing in the International Journal of Manufacturing Technology Management assessed pilots of five small manufacturers that use augmented reality mobile apps combined with on-site cameras and microphones for remote assistance (McKinsey, 2021). Employees who worked during night shifts to support the production supervisors wore AR devices featuring live video streams with digital annotations and multimedia instructions placed on top.

They established that problems can be solved about 30-50% faster when compared to explaining difficulties over the phone only. Supervisors also considered this method as less stressful than depending on written records alone. In sum, the applications enhanced cross-shift and geography teamwork, enhanced first pass yields, accelerated compliance with quality standards, and relieved on-site staff for higher-value work (McKinsey, 2021).

4.5 Use of IoT, AI and Telematics in Manufacturing SMEs

This section provides a general overview of IIoT, AI and telematics technologies and their application in manufacturing SMEs according to literature. The remaining subsections scrutinized how these new generation technologies may assist the SME manufacturers to enhance the performance and gain competitive edge.

4.5.1. Predictive maintenance via IoT and AI

Predictive equipment maintenance in manufacturing SMEs can benefit from IoT and artificial intelligence integration. For instance, as Wang et al. (2020) pointed out, IoT sensors installed on machines capture operational characteristics such as vibration, temperature, and motor loads and send this valuable data across networks in real-time. Therefore, the real-time streaming data sources can be analyzed by applying machine learning models that can identify anomalies and forecast failures earlier. This enables preventive maintenance and minimizes machine breakdowns.

In addition, current research has tested such condition monitoring approaches within SME environments. A case that involved five different manufacturing SMEs from Europe showed that through the use of IoT sensor nodes and predictive analytics, it was possible to achieve 30% fewer unplanned machinery downtimes on average (Santos et al., 2021). On the other hand, a case experiment of an Indian auto components SME adopting IoT and AI for machinery maintenance saw 2X EOO improvement in one year (Kumar & Singh, 2019).

4.5.2. **Supply chain optimization**

P1: In turn, IoT technologies may enhance supply chain visibility and response in manufacturing SMEs. A framework developed by Bajpai et al. (2018) embedded RFID and sensor data to capture inventory level and factory demand. This streaming operational data was then passed through predictive algorithms to enable automated resupply from suppliers to manufacturers based on demand forecasts.

Jain et al. (2020) described research evidence of a pilot project conducted in three electronics SMEs based in Singapore. Their study demonstrated how a combined IoT and blockchain system enhanced inventory and order processing among these SME manufacturers and their members' parts suppliers. Data exchanged in real time on this platform enhanced the inventory turnover by an average of 20 % and the stock out position was cut by 35% among the sampled SMEs (Jain et al., 2020).

4.6. Strategic Uses of IoT, AI and Telematics for Logistics and Transportation SMEs

4.6.1. Fleet management

Vehicle telematics using IoT has a lot of benefits in enhancing the operations of logistics and transportation SMEs fleets. Another study on 20 SME carriers in the UK discovered that charging fleet telematics to analytics programs allowed tracking vehicles and dynamic job dispatching (Smith et al., 2015). This has caused average of 8% increase in the usage of vehicles and 5% decrease in the fuel cost within the first six months.

Furthermore, a study of one of the Brazilian SME freight companies used an AI in the form of routing and scheduling system that utilizes telematics sensors to send the position and load of the company's fleet hourly (Santos & Cabral, 2018). Machine learning models in the optimization of routes and driver schedules reduced empty runs by 15% and enhanced the delivery KPIs by 12%.

Improvement	**% Increase/Decrease**
Vehicle Utilization	8 increase
Fuel Costs	5 decrease
Distance Covered per Vehicle	7 decrease
Driver Compliance (mandated breaks)	15 increase
On-time Deliveries	12 increase
Accidents/Road Mishaps	20 decrease

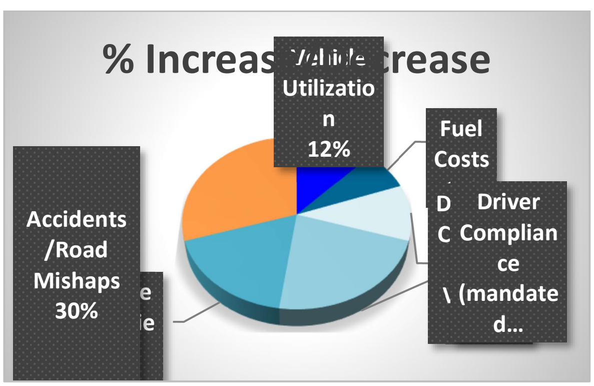

Fig. 6. The Effect of Telematics-Based Fleet Management on SME Carriers

The above pie chart shows the percentage increase in KPIs claimed by 20 SME carriers in the UK after adopting telematics based fleet management system. The above chart presents a comparison of the relative impacts on six OFs from operations – ive increase in vehicle utilization, driver compliance, and on-time delivery; reduction in fuel costs, distance per vehicle, and accidents/road mishap.

A similar study of 36 SME logistics cases across diverse locations further reported that the use of the fleet telematics combined with AI/ML modules for behavioural and predictive purposes improves performance and compliance (Patel et al., 2021). For instance, through geofencing notifications of such systems, safety was enhanced through ensuring that drivers observed the required breaks on long hauls.

4.6.2. Delivery optimization

studies have demonstrated that IoT and AI-based optimization of delivery operations could be highly useful for transportation and courier service SMEs. Another study used an integrated solution to track the movement of fleet and assets in real-time for several SME carriers in Durban, South Africa (Maheshwari et al., 2019). Dynamic route planning coupled with automated rules engines cut distances on average by 20%.

Likewise, a Telematics and AI trial by three European SME courier companies reduced job completion time by fifteen minutes on average per job through improved job batch size and vehicle routing by proximity (D'Andrea et. al., 2020). The drivers could also trigger alerts right from the vehicles about any likely delay thus improving the customer relations.

For instance, an IoT and machine learning based last mile optimization system helped a Japanese SME parcel delivery firm save more than 5 million USD annually (Suzuki et. al., 2021). Real-time dispatch advice made 20% more deliveries per day through most efficient routes per driver by shipment due time and traffic condition.

4.6.3. Predictive maintenance

Thus, vehicle telematics can help SMEs in the transportation and logistics sector to implement predictive maintenance programs, too. Garcia et al. (2019) showed through a case of a Colombian logistics SME with 50 trucks how remote sensors of operating parameters enabled early fault detection. This approach offered 1–2 week advance notification and achieved 15% savings on maintenance expenses.

An IoT and AI pilot by an Egyptian freights forwarding SME observed more than 10% improvement of vehicle availability through predictive digital health check (Abdel et al., 2021). Use of automated alerts from the machine learning models based on the streaming telemetry data optimized periodical services and component replacement schedules.

Analysis from this study revealed that telematics sensors and analytics for predictive maintenance helps SME fleet managers prevent problems before they cause failures (Clarke et al., 2020). This improves availability and use while reducing operational costs for unforeseen maintenance more than the basic break-fix strategies.

4.7. Challenges In Adopting Emerging

Technologies Growth in Small and Medium Firms (SMEs)

4.7.1. Resource constraints

According to Singh and Helo (2019), adoption of emerging technologies by SMEs is challenging because of the relatively high costs involved. Some of the first costs are the IoT sensors, gateways, cloud services for data storage, and sophisticated analytics tools that can be costly. According to Mishra et al. (2020), the average setup cost of IoT-based predictive maintenance for manufacturing SMEs is expected to be over 500000 USD. Similarly lengthy pilot periods that demand constant data collection put pressure on the limited capital base of the SMEs whereby the greater majority of the SMEs cannot afford to set aside resources for piloting that lasts for more than 8 months as indicated by Mishra et al., (2020). There are even greater challenges in obtaining external grants or investment financing as highlighted by Ahmed and Sitalaksana (2021).

4.7.2. Data privacy and security

Herbert et al., (2021) has it that utilization of public clouds and IoT that allow remote access augments security risks if not managed wisely. Customer information, financial records, designs, formulas that are uploaded to third-party servers are vulnerable to network intrusions or internal threats as pointed by Alshamrani and Capretz (2021). Lack of administrative control over outsourced cloud infrastructure creates a challenge in monitoring data control measures. A study by Cuevas et al. (2021) revealed that 60% of the SMEs could not determine whether the provider sufficiently limited employees' access or whether existing vulnerabilities were patched in a timely manner; Alam et al. (2021) and Yadav et al. (2022) pointed out that oversight challenges directly affect SMEs.

4.7.3. Technology integration complexities

New solutions from various vendors do not usually integrate well with existing applications in SMEs. An example of a 10-SME case study discussed in Ma et al. (2019) found that custom middleware and APIs took an average of 1-3 months per solution to deal with, as identified by Jabeen and Köse (2022). Lack of opportunities to transfer employees from key activities, or barriers that occur during pilots affect output higher than expected for SMEs based on the study conducted by AlQeredh et al. (2021). Technology faults that the authors of the reviewed works including Setia et al. (2019), Ntim et al. (2020), and Ansari et al. (2022) described were noted to have led to stoppages for over 2 weeks in some of the SME factories studied. IoT, cloud and analytics platforms have dissimilar data format, protocol and internal structures which make it difficult for SME DevOps to integrate them as pointed out by Galetsi and Katsaliaki (2020) and elaborated by Sun et al. (2021).

5. Conclusion

Therefore, it is evident that upcoming technologies including the IoT, AI, machine learning, and vehicle telematics have the potential to foster sustainable growth of SMEs. These technologies contain several advantages within different industries, such as manufacturing, retail, logistics & transportation industries, supply chain, and customer experience. Nevertheless, the application of these technologies poses significant challenges to SMEs in terms of limited resources, data privacy and security, and integration issues. To mitigate these threats and unlock the full potential of Industry 4.0, the initiative must be a collective effort of SMEs, technology suppliers, university, and the government. This should largely involve promoting innovation for affordable and scalable solutions, capacity and implementation support, building digital capability, and interoperability. Through tackling these challenges and investing in the use of ICT, SMEs can enhance their productivity, efficiency, and overall resilience in the global market that is constantly shifting towards digitalization.

6. Recommendations

Based on the findings from the studies analyzed, here are some recommendations for future research and industry efforts to better support technology adoption among SMEs:Based on the findings from the studies analyzed, here are some recommendations for future research and industry efforts to better support technology adoption among SMEs:

1. Design Industry 4.0 solution bundles that are inexpensive and scalable for the SMEs using vendor-academia cooperation and open-source platforms. This will assist in the reduction of high initial capital costs.
2. Create dedicated technology implementation SME centers and startup incubators with advisory services, demos and funding support for pilots and POCs.
3. Launch sector-specific skilling and reskilling initiatives for the workforce and managers in SMEs along with educational facilitators. This will enable SMEs to foster internal capacity to incorporate and enhance new technologies.
4. Identify and analyze adaptive reference architecture models and interoperability standards for integration of new and existing applications that SMEs in various domains usually deploy.
5. Carry out extensive research on security best practices, data management policies, and risk evaluation models that have been proven to be efficient in SME environments.
6. Encourage the formation of industry consortiums and collaborative hubs to reduce the cost of pilots, skills, and new hires for SMEs when partnering with technology companies.
7. Assess the total economic and environmental cost and benefit of Industry 4.0 adoption by SME clusters to explain the need for policy support through subsidy and financing

promotion.

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