

Digital Transformation in SMEs in Heavy Freight Transport Sector

Claudia Milagros Alanoca Alvarado and Shiva Abdoli

School of Mechanical & Manufacturing Engineering
University of New South Wales, Sydney, Australia
z5509684@ad.unsw.edu.au, s.abdoli@unsw.edu.au

Abstract

With the acceleration of digital transformation (DT), many Small and Medium Enterprises (SMEs) have had difficulty adapting, particularly in sectors such as heavy freight transport. This study investigates the challenges, barriers, needs, and expectations of SMEs which operate in the heavy freight transport sector, particularly in developing countries with a focus on digital transformation. To this end, this study proposes a methodology by application of the Quality Function Deployment to translate business needs into technical requirements, explores the available digital technologies that align with SMEs' needs and analyzes their applicability. The proposed methodology provides a structured approach for SMEs in decision making regarding analysis and adopting digital technologies by considering their unique context and needs.

Keywords

Industry 4.0, Heavy Freight Transport, SMEs, Digital Transformation, Quality Function Deployment

1. Introduction

The increasing influence of industry 4.0 and digital transformation (Malaibari et.al 2024 and Ji and Abdoli 2023) has transformed industries across the world, enabling organizations to enhance efficiency, adaptability, and customer focus. Digital transformation involves the adoption of new technologies such as the Internet of Things (IoT), artificial intelligence (AI), big data, 3D printing, and cloud computing to redefine business processes and value creation models. Large enterprises have increasingly implemented these technologies. However, Small and Medium Enterprises (SMEs), particularly those operating within the heavy freight transport sector, have faced significant challenges, adapting to digital advancements (Faisal, R. et al., 2023). The SMEs within this sector, often limited by financial and technical constraints, were particularly impacted, highlighting the necessity of digital transformation decision support systems to support their long-term viability, and competitive advantage (Keskin, et al., 2010).

Despite the recognized significance of digital transformation, a review of existing literature reveals considerable research gaps. Most studies predominantly focus on larger organizations, maritime and urban freight sectors, or organizations operating in developed countries (Collaço et al., 2022). There is limited attention given to SMEs in heavy freight transport, especially in developing countries. Furthermore, there is a notable lack of studies applying engineering methodologies (Philbin et al., 2022). This study aims to address the identified gaps by investigating the challenges, barriers, requirements, and expectations of SMEs operating within the heavy freight transport sector regarding digital transformation. In addition, it explores how the application of the QFD methodology can align business needs with the adoption of digital technologies. A comprehensive literature review is completed, providing valuable insights into key opportunities, challenges, and technological advancements in the sector.

This study therefore contributes by proposing a structured QFD-based framework to align SMEs' business needs with digital technologies, addressing this gap

2. Methodology

We have defined the following research questions to critically review the literature surrounding the practical integration of Industry 4.0 technologies and digital transformation within SMEs in Heavy Freight Transport Sector.

1. What are the challenges, barriers, needs, and expectations of SMEs in the heavy freight transport sector regarding digital transformation, in developing countries?
2. How can the business needs of SMEs in the heavy freight transport sector be translated into technical requirements to support their digital transformation?

We conducted a structured literature review on databases including Scopus and Web of Science, using keyword combinations including Industry 4.0, SMEs, Digital Transformation, and Heavy Freight. Only peer-reviewed publications were considered. We initially screened titles and abstracts to ensure relevance, selecting studies that addressed the adoption of Industry 4.0 or digital transformation technologies in SMEs and particularly the heavy freight transportation sector. The selected papers were then analyzed and categorized based on key enabling technologies, identified barriers and challenges. This process allowed us to identify research gaps and informed the formulation of our proposed methodology.

The literature review is conducted in such a way that gives the reader the current scenario, from understanding the importance of Digital Transformation for SMEs. The process of review and how it leads to the derived insights is shown in Figure 1 which is explained further in the next sections.

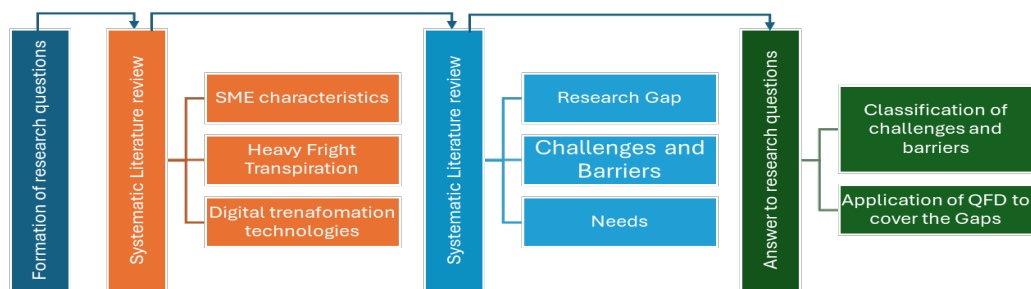


Figure 1. Research approach

3. Review Results

3.1 Digital Transformation

Researchers in (Gamage 2021) conducted a study in which they identified the key elements of digital transformation. The key elements include the use of digital technologies, internal operations, customer experience, digital innovation, value creation, products and services. The key elements are grouped into three main categories within a digital transformation framework: business transformation, digital technologies transformation, and society transformation. Digital transformation is not solely about technology; it also requires a transformation of people and culture within the organization. Therefore, companies undergoing digital transformation typically face three main types of challenges that are aligned with technology, finance, and human resources (Abdoli and Djukic 2025). For that reason, to have a successful digital transformation, organizations must align these three factors toward a common goal. The adoption of digital technologies such as Artificial Intelligence (AI), Big Data (BD), the Internet of Things (IoT) and Cloud Computing (CC) allow organizations to speed up their innovation processes and deliver products that align more closely with customer requirements. Organizations that can rapidly incorporate these technologies into their operations gain a competitive advantage over the competitors by responding more effectively to market changes and new technologies (Hai et al., 2021). Figure 2 shows Digital transformation technologies. For instance, Internet of Things (IoT) and Industrial Internet of Things (IIoT) describe systems in which physical objects are embedded with sensors along with software and integration tools to enable real-time monitoring and data sharing across distributed networks (Collaço et al., 2022). On the other hand, cloud computing technology is not just a technological advancement, it serves as a transformative force for modern supply chains and the broader global business environment. Cloud computing empowers companies to create supply chains that are more robust, efficient, and adaptable by increasing transparency, fostering collaboration, minimizing operational costs, and enhancing flexibility (Xie et al., 2024).

Incorporating cloud computing into strategic decision-making is especially critical, as it provides quick access to relevant data and advanced analytical tools. This enables organizations to respond to market changes and refine their innovation approaches to align with evolving conditions (Philbin et al., 2022).

In the case of cyber-physical system (CPS), also named the intelligent system (Ji and Abdoli 2023), is a computer-based setup where a physical mechanism is managed or monitored using algorithmic controls. (Collaço et al., 2022). Another digital technology is big data which is not just a collection of information, it is a transformative tool that redefines our understanding of the world. Big data can effectively address some of the most pressing challenges of the new society, from climate change to social problems, by providing more informed decisions, efficient communication, improved coordination, and precise actions. The impact of big data on organizing and managing society will extend as data analysis technologies evolve, opening new possibilities for innovation and progress (Philbin et al., 2022).

Another popular digital technology is Artificial intelligence, it optimizes existing processes and provides preparation for more innovative, flexible, and sustainable production models by enhancing efficiency, precision, and adaptability. With artificial intelligence organizations can create products customized and optimized for specific consumer requirements in the design and development phases, it will improve customer satisfaction and create opportunities for new business models based on customized and on-demand production (Philbin et al., 2022).

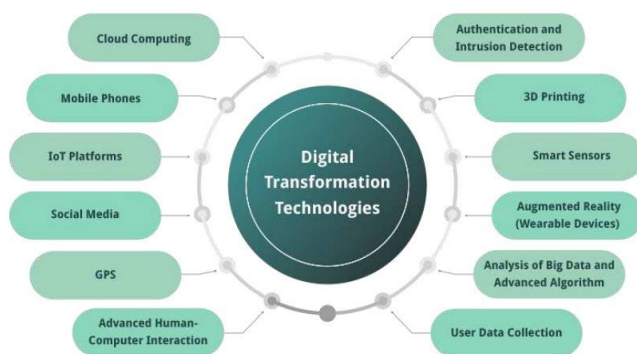


Figure 2. Digital transformation technologies (Hai et al., 2021)

3.1 SMEs Characteristics

Researchers in (Melo et al., 2023) mentioned that until January 1996, businesses were classified as small or medium-sized based on the number of employees if they have fewer than 500 employees, it was an SME. Within this classification, micro-enterprises had between 1 and 9 employees, small enterprises ranged from 10 to 99 employees, and medium enterprises included those with 100 to 499 employees. While traditional definitions used employee numbers, more recent classifications emphasize revenue and asset size. The organization of economic cooperation development defined SME's as 'non subsidiary independent enterprises where the salient features are number of employees and extent of financial assets' (De Sousa Jabbour et al. 2023). A study stated that almost 99% of firms identified themselves as SME in Asia, therefore influencing the social and economic aspects with being responsible for providing employment for more than half of the workforce across. Likewise, Europe is seeing 70% of employment in the manufacturing sector being done by SMEs (Garetti and Taisch, 2012).

3.2 Digital Transformation Challenges for SMEs

Despite the transformative potential of these digital technologies, SMEs face significant barriers, such as financial constraints as noted by Faisal et al. (2023), with many SMEs unable to invest in those sophisticated digital systems. Moreover, limited technical expertise makes it difficult to implement and manage digital tools effectively and SMEs are often more vulnerable to cybersecurity threats due to a lack of specialized IT security teams. Resistance to change within the organization is also an obstacle, particularly in sectors such as heavy freight transport where traditional practices are deeply solidified.

Researchers in (Hai et al., 2021) mentioned the challenges which are financial Constraints because for many SMEs, the cost of investing in digital technologies is a significant barrier. Unlike large companies, SMEs often face greater

difficulties in securing funding from financial institutions to support the technological upgrades or implement digital transformation in the business. Another challenge is the limited Technical Expertise, a big challenge faced by many SMEs is the shortage of technical skills needed to successfully implement digital transformation and manage those technologies. Furthermore, Cybersecurity Concerns is another challenge because when SMEs implement digital transformation, they become more vulnerable to cyber threats. As they are small businesses, they do not have a cybersecurity plan for those cases. This lack of preparation for cyber-attacks heightens their exposure to data breaches and financial losses, which in turn discourages many SMEs from fully embracing digital transformation. Finally, Resistance to Change is a challenge faced by SMEs due to the organizational culture and resistance to changes. The lack of support from employees and management makes the digital transformation efforts fail. Figure 3 shows those key challenges faced by SMEs.

Researcher in (Ghobakhloo et al., 2022) discussed about the challenges of SMEs in developing countries because despite the clear benefits that Industry 4.0 offers for SMEs, adoption rates of digital technologies such as AI, augmented and virtual reality, blockchain, CPS, IoT, and simulation remain moderately low among these businesses. The results of the systematic literature review (SLR) applied in the study show that SMEs tend to prefer traditional information and digital technologies, such as ERP systems, over more disruptive Industry 4.0 technologies like blockchain, digital twins, and extended reality. While some may overestimate the extensive adoption of Industry 4.0 technologies in SMEs, the findings indicate that many SMEs are still struggling with the early stages of DT. SMEs in developing countries are particularly lagging in this area, and the situation is even more challenging for those SMEs operating in less developed countries.

Researchers in (Dong et al, 2021) concluded that most SMEs depend on external assistance to implement disruptive Industry 4.0 technologies. They argue that governments have a crucial role in facilitating the digital transformation of SMEs, particularly by easing the early stages of digital adoption. The results of the SLR in the study, indicate that government support should focus on bridging the infrastructure gap, addressing financial challenges faced by SMEs by offering incentives for digital investments, and closing the digital policy gap by creating regulations that promote cybersecurity, prevent digital monopolies, and foster digital inclusion. Emerging technologies have introduced new challenges that require innovative strategies and policies from governments, and they need to be developed quicker than ever before.

To navigate these digital transformation challenges, leaders can utilize a five-step model proposed by Saldanha to achieve successful transformations. Figure 3 shows the five-stage model for successful digital transformation proposed.

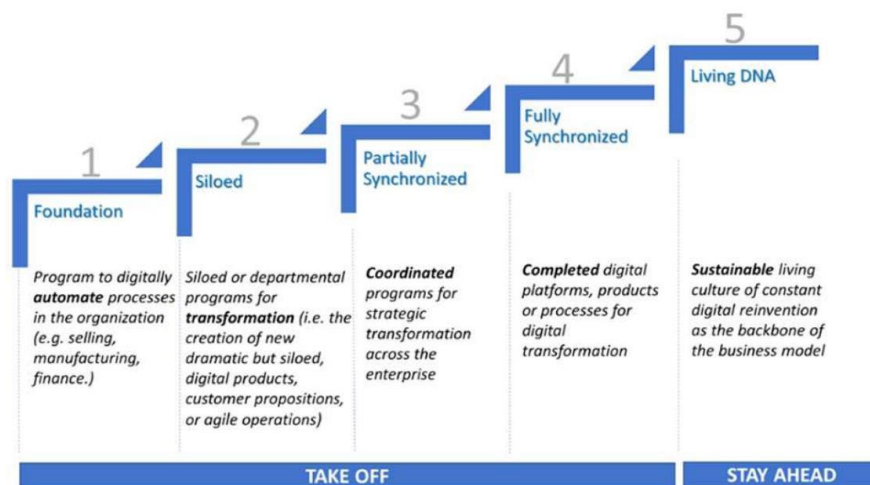


Figure 3. The five-stage model for successful digital transformation (Hai et al., 2021)

3.3 Challenges in Heavy Freight Transport

In the context of heavy freight transport sector, researchers in (Karam et al., 2022) reveal that freight logistics industry has experienced growth and development in recent decades and, despite some dip after the economic cutback in 2008,

has increased steadily in recent years, not the least in urban areas where Internet sales and home deliveries are increasing quickly. At the same time, it has been widely recognized that many of the current logistics systems are not sustainable and attempts to improve operations rely on new technologies that will increase in the future. The advent of the industry 4.0 challenges the current logistics industry but, at the same time, provides opportunities to use disruptive technologies to invent new business models at the same time as it supports current ones (Puniani and Abdoli 2025). This trend has resulted in increased interest from various stakeholders in understanding the impact of emerging technologies on heavy freight transportation, together with the support of decision-making in logistics management.

Heavy Freight transport plays a crucial role in logistics and distribution and contributes significantly to both economic and social development. These factors have led to increased transport volumes, influencing the cost, operations, and overall efficiency of freight transport. Efficiency and costs in freight transport are shaped by a range of economic, social, and environmental factors, which often require balancing. Improving transport efficiency can lead to reduced costs and lower environmental harm. Furthermore, the effectiveness of freight transport directly enhances the reliability and performance of supply chains. Each mode of transport such as road, rail, air, and maritime offers unique characteristics in terms of cost, delivery speed, and service quality. Road transport carries the bulk of freight, whereas rail is more energy-efficient and environmentally friendlier (Mavi, et la., 2022).

However, road freight transport is also characterized by high operational costs, exposure to environmental factors, and high maintenance demands. Digital technologies offer solutions to many of these challenges. For instance, IoT-enabled telematics can monitor vehicle health in real time, AI can dynamically adjust delivery routes to reduce fuel consumption, and cloud-based platforms can enhance coordination among supply chain partners (Dong et al., 2021). Nonetheless, heavy freight SMEs often lack the resources necessary to implement those technologies comprehensively.

Although studies in urban and international freight offer useful parallels, this paper focuses specifically on heavy freight SMEs where resource limitations are most acute.

Researchers in (Lindholm et al.,2022) discuss how Business model innovation (BMI) remains relatively underexplored in research related to urban freight transport. The study reviewed literature and reinterpreted five cases of attempted BMI within Sweden's urban freight transport sector. In Swedish urban freight transport sector is divided into four size-based segments: goods up to 100 kg (parcels); general cargo (Euro-pallets) between 100 and 1000 kg; part loads of 1000 to 5000 kg; and full loads of more than 5000 kg. Furthermore, in Sweden, pallet and parcel delivery is undertaken by a few dominant freight forwarders that rely on numerous smaller independent transport operators that often operate on a local or regional scale. Additionally, the study provides the Figure 4 that illustrates how digitalization generates value by increasing the quality and speed of information.

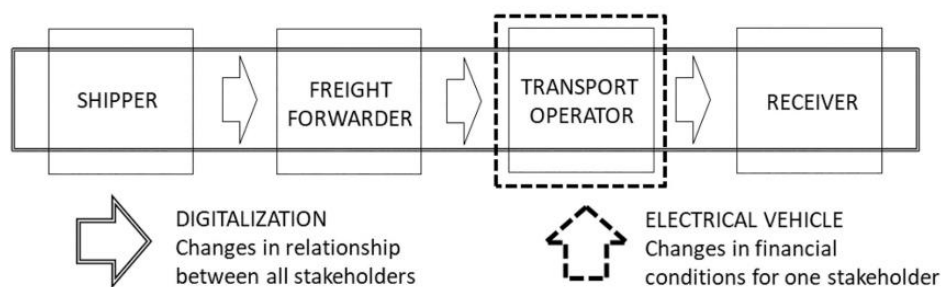


Figure 4. Location of BMI in the urban freight value chain (Lindholm et al.,2022)

On the other hand, research in (Dong et al., 2021) provides the automation systems, information systems, materials and energy systems (AIME) which represent the four major pillars supporting freight transportation in the digital era. In general, nine emerging technologies have been identified in the research: 3D printing, artificial intelligence, automated robots, autonomous vehicles, big data analytics, blockchain, drones, electric vehicles and Internet of Things. Figure 5 shows it.

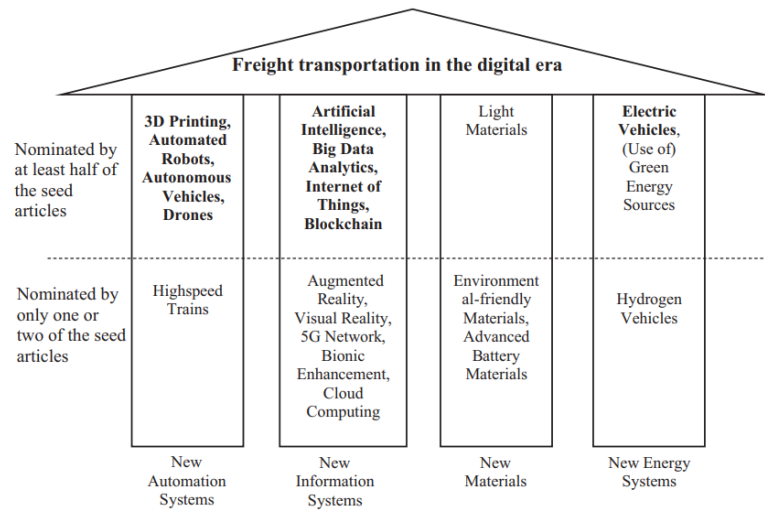


Figure 5. automation systems, information systems, materials and energy systems (AIME) (Dong et al., 2021).

In contrast, researchers in (Ferreira et al., 2019) cover international freight transportation, which refers to the physical movement of goods across countries such as ships, airplanes, trains, trucks, pipelines, or intermodal methods. It often involves different stakeholders, such as shippers, carriers, freight forwarders, third-party logistics providers, and customs authorities from two or more nations for each shipment. Compared with domestic transport, international freight is distinguished by larger shipment volumes. For instance, container ships carrying over 10,000 TEUs, longer travel distances like intercontinental routes, larger vehicles, big infrastructure, and border inspections increase management complexity. Therefore, there are research challenges related to managing international freight, from demand forecasting to operational planning, and from asset maintenance to predicting on-time performance. Nonetheless, with growing globalization, the crucial role of international freight transportation has become vital over time.

Researchers in (Mefid and Ridhaningsih 2022) investigated freight transport and how it has long been a critical component of the supply chain. Since 2020, different studies have explored how COVID-19 has impacted freight logistics and analyzed potential strategies to mitigate the effects. Some of the identified impacts include shortages of transport resources, increasing operational costs, and volatile demand for transport services. Numerous studies have also proposed strategies to manage those challenges, considering the importance of the issue, they summarize the current research on freight transport during the COVID-19 pandemic and suggested future research avenues. Unlike past pandemics, which often affected many specific countries, COVID-19 has had a global impact, affecting nearly all areas of human activity.

3.4. Gaps

After reviewing the literature, there are clear gaps. For instance, the Lack of specific studies in the Heavy Freight Transport sector, the existing literature mostly focuses on sectors such as maritime, urban freight transport, but not the heavy one, or general logistics. There is an absence of studies that investigate the digital transformation specifically within the heavy freight transport sector. Therefore, there is a gap in understanding the challenges and technological opportunities of that specific sector.

Moreover, there is a Lack of studies focused on developing countries. The studies mostly covered developed countries, particularly Europe, North America, and Asia. There is a lack of research focused on digital transformation in SMEs and especially in the heavy freight transport sector of developing countries, such as countries in Latin America. This is a clear gap that limits the application of existing findings to different economies and societies.

As researchers in (Nankoomar and Quilling 2023) argue, the experiences of SMEs in developing countries differ notably from those in developed countries. Infrastructure limitations, lower levels of digital education, and limited access to affordable digital solutions create high barriers. For heavy freight SMEs in Latin America, Africa, and parts

of Asia, these challenges are intensified by regulatory complexities and volatile economic conditions (Keskin et al., 2010). Thus, digital transformation frameworks designed for European or North American SMEs may not be adequate without significant adaptation.

In addition, there are very few studies that cover SMEs in the freight transport sector; the existing literature mainly covers the freight transport sector in general without focusing on SMEs, and only a few studies mention or discuss SMEs in a general way. The SMEs have different financial and human resource capabilities, also the structure is different compared to larger enterprises. This affects how to approach and implement digital transformation.

Another important gap is the Lack of application of engineering tools. Most literature applied theoretical or descriptive methodologies, despite the emphasis on digital transformation, which includes technologies such as IoT, AI, blockchain, and ERP systems, which involve engineering knowledge, there is a lack of application of them or any engineering tool. Therefore, there is a clear gap and opportunity to evaluate the implementation of those technologies.

These gaps justify the need for structured engineering tools such as QFD, which have not yet been applied in this domain. There are limited applications of engineering tools to facilitate digital transformation among SMEs, while strategic frameworks are abundant. Therefore, Quality Function Deployment (QFD) methodology emerges as a promising engineering tool to address this shortfall. Originally focused on translating customer needs into engineering characteristics for product development, QFD has been adapted for a different strategic planning context, including digital transformation.

4. Proposed approach

The literature review has provided a comprehensive overview of the current scenario, covering the importance of SMEs, along with their respective advantages and disadvantages, the heavy freight transport sector and its challenges.

The QFD method has been widely used in the SE approach to align customer requirements with engineering characteristics (ECs) through one of its most famous matrices known as the House of Quality (HOQ) matrix. (Danis et al., 2025)

In this paper, we look at a novel approach of applying for a QFD. In the context of SMEs, we apply QFD to identify organizational needs and translate them into technical requirements for digital tools. Studies such as in (Vărzaru and Bocean 2024) highlight the importance of aligning technological solutions with business strategy to ensure successful digital transformation outcomes.

Applying QFD methodology allows SMEs to prioritize digital initiatives based on their strategic impact and resource availability, providing a well-structured pathway toward digital transformation. Methodologies like Quality Function Deployment (QFD) provide a well-structured framework to bridge the gap between business needs and technological solutions, but their application in this context remains limited and unexplored. Furthermore, another methodology, such as SWOT can enhance its effectiveness by ensuring that internal and external factors are suitably considered.

In this section, the answers to the first three questions based on the literature review are provided. The results provide foundation for the proposed approach which is the answer to the last research question.

1. What are the available digital technologies most aligned with the SME needs?
2. How can QFD methodology help SMEs in adopting digital technologies effectively?

2.1 What are the challenges, barriers, needs, and expectations of SMEs in the heavy freight transport sector regarding digital transformation, in developing countries?

The tables presented in this section are the outcome of a structured and critical literature review, as detailed in previous. The review included over 30 peer-reviewed studies that were thematically analyzed and categorized using criteria aligned with the objectives of. The barriers and enabling technologies identified here are not simply listed but are the result of comparative synthesis across studies. (Table 1)

Table 1. Challenges and Barriers

Challenges	Barriers to overcome
Limited workforce skills in working with digital technologies.	Lack of financial resources to afford the implementation of digital technologies. In the short run the lack of skill labor impact implementation, but this can be mitigated with proper training therefore not a long-term threat.
Poor connectivity, unreliable internet access, or inefficient power supply.	Facilities such as high speed and stable internet connection, constant electricity supply, data centers, are needed Limited internal technical expertise within the SMEs, to implement, operate, and maintain those technologies.
Lack of IT departments or digital investment strategies.	Deficient policy support in developing countries due to inconsistent government policies and a lack of legal protection.
Resistance to the change because of organizational culture, as employees have long relied on traditional business practices.	Cyberattacks are increasing, and SMEs are not prepared to handle them; they are often not well-equipped to respond effectively. Management in SMEs usually might resist to change as they fear losing out existing revenues and market share which is a big challenge in implementing digital transformation
Lack of economic resources	SME's have lesser Free Cash Flow compared to larger firms to implement new technologies
Need for tangible short-term benefits	SMEs due to their poor Free Cash Flow need to see tangible benefits in short run to apply new methodologies and justify investments
Lack of training or implementation frameworks	Current methods have not included SMEs and their challenges when it comes to digital transformation
Low degree of standardization	A general implementation framework for digital transformation does not exist. Firms are confused about what standard their machinery are set; data collection and analysis techniques need to be achieved
Challenges in value chain integration	Products/services involve a series of stakeholders. Having them on board with digital transformation is necessary, which each might have their own barriers to adopt
Disruption to existing jobs	Digital transformation may lead to loss of jobs; the goal is to reduce the number of jobs loss to a minimum via training and upskilling.
Lack of digital strategy along with resource scarcity	Lack of positive outlook towards digitization stemming from underlying issues such as cyber security
Possible job polarization	With the need to upskill, many older employees may not be able to catch on with the needed requirements and feel putting their jobs at risk
Concerns with cyber security/safety of workers wearing wearable tech	These techs post threat to worker privacy and firm privacy as believed majorly in many polls conducted
Increased offshoring of work	A problem in first world countries causing domestic job market disruption, companies opting to offshore their work to take advantage of cheaper job market.
Data related issues	Collection, storage and analysis of data require the use of energy, which is expensive economically and environmentally. Use of conventional energy resources pushes firms away from achieving I5.0 commitment to sustainability and due to the high cost might be impossible for smaller firms
Lack of homogeneity of remote devices	Many different devices are used to manage the same process, but lack of common User Interface may complicate their management.
Low technology standardization	The firms currently push clients to buy all technology from a single firm to ease up their UI experience which makes it costly

We can cluster these problems on the core barriers to implementation

- 1- Lack of training and implementation methods.
- 2- Lack of economic resources
- 3- Negative management outlook towards change and innovation-
- 4- Low degree of standardization.

This synthesis constitutes a major contribution to the field, offering a consolidated evidence base that maps key challenges and actionable enablers for transitioning SMEs. To our knowledge, this is the first study applying QFD to systematically translate SME needs into digital technology requirements in the heavy freight transport sector (Table 2).

Table 2. Need and expectation of Heavy Freight Transport Sector

Needs	Expectations
SMEs need digital technologies that are adaptable and affordable, enabling them to adopt basic features now and expand later if possible.	Reduce operational costs by optimizing fuel use, enhancing delivery scheduling, and minimizing time - out.
Employees need to receive practical training on digital tools and also on the purpose and benefits of digital transformation.	Improve the customer service and satisfaction, SMEs would implement digital tools that help track shipments, anticipate delays, and provide digital documentation easily and quickly
SMEs need tools that function with unreliable internet, frequent power outages, and basic hardware, issues that occur in developing countries.	SMEs expect to reduce labor hours and minimize human errors by applying digital tools and automating the processes.
SMEs need digital systems that align with their existing processes and can replicate the required functions before attempting to replace them entirely.	In a market dominated by many companies in the heavy freight transport sector, some with advanced digital tools, SMEs expect to stay competitive, respond faster, and get more contracts with the digital transformation.

2.2 How can the business needs of SMEs in the heavy freight transport sector be translated into technical requirements to support their digital transformation using the QFD methodology?

The QFD approach includes the development of a House of Quality containing the attributes:

1. 1. Stakeholder requirements
2. 2. Importance rating for each stakeholder requirement
3. 3. Features / functional requirements
4. 4. Relationship scores between stakeholder requirements & features

Required outputs from using a QFD include a weighted score for stakeholder requirement and a technical importance score for each feature.

To address the second research question, a QFD matrix was developed, Shown in Figure 6, using literature and illustrative Latin American SME cases. The QFD matrix translates business needs identified through conceptual case and review results into technical requirements based on digital tools, such as Artificial Intelligence (AI), ERP, SAP, Blockchain, IoT, and others detailed in the matrix. Each customer requirement (business needs) was assigned an importance rating (5, 4, or 3) while the technical requirements were linked through relationship weights (strong, moderate, weak, or just no relationship). Additionally, a competitive analysis was included to compare the current performance of Latin American SMEs against the digitally advanced company in the sector and global benchmark, helping to identify key business needs for improvement. The QFD matrix serves as a strategic tool for digital transformation initiatives aligned with customer expectations.

Customer Requirements	Importance	Artificial Intelligence (AI)	Enterprise Resource Planning (ERP)	Systems Applications and Products (SAP)	Digital Twin Technology	Blockchain	RFID (Radio Frequency Identification)	Internet of Things (IoT)	Cloud Computing	Real-time Tracking & Monitoring Systems	SMEs in developing countries	Competitor 1	Competitor 2	Target	Ratio	Special Emphasis	Weight
Efficient routes, documents, and clients management	5	3	9	9			1	3	3	1	3	5	3	5	1.67	1.5	12.5
Good connectivity and access from remote locations	4							3	9	3	1	5	3	4	4.00	1.2	19.2
Reduce manual and human errors and minimise delays	5	9	3	3	3	1				3	3	3	3	4	1.33	1.2	8
Simple and affordable system implementation	4	3	3	1	1	1	1	3	3	9	5	3	3	4	0.80	1.5	4.8
Improve customer service and satisfaction	4	9	9	3					3	3	5	5	3	3	0.60	1.2	2.88
Improve competitiveness within the sector	5	9	9	3		1		1	9	3	3	5	3	5	1.67	1.5	12.5
Maintenance prediction and Fleet management	5	9	3	3	9					1	3	5	3	5	1.67	1.5	12.5
Live monitoring, alerts, and location	5	3			1		9	9		9	5	5	5	3	0.60	1.2	3.60
Importance of technical parameters		385.62	289.32	187.44	32.4	25.3	49.7	154.4	345.84	228.34							

Figure 6. QFD matrix translating business needs

The Quality Function Deployment (QFD) matrix generated identifies and prioritizes the digital technologies most aligned with the business needs of SMEs in developing countries. The results reveal that Artificial Intelligence (AI) ranks the highest in importance (385.62), followed by Cloud Computing (345.84) and Enterprise Resource Planning (289.32). This indicates that these key technologies should be given strategic focus for the digital transformation, as they can offer the greatest potential to improve operational performance and competitiveness in the SME sector.

Regarding the second sub-question, the QFD methodology supports SMEs by providing a structured decision-making tool that translates the business needs into technology implementation strategies. With the matrix, SMEs can identify which digital technologies will have the greatest impact on their processes based on their most critical needs and expectations. Additionally, the inclusion of a competitive analysis allows SMEs to compare themselves against more advanced competitors and set digital transformation targets. This methodology helps SMEs to prioritize investments in the correct technologies that align most directly with their business goals and customer expectations to improve their competitiveness.

3. Conclusion

This paper contributes to the field in two ways, it first identified and clustered barriers to digital transformation implementation barriers in SMEs of heavy freight sector and the second is proposing a novel QFD approach to analyse the relation between barriers, the needs and technological solutions. We have identified key insights that hold significant implications for both researchers and practitioners working toward digital transformation in SMEs in heavy freight transportation sector. Our structured ranking of barriers helps differentiate between surface-level challenges and deeper root causes. For example, issues such as digital skill shortages and resistance to AI adoption are closely linked to broader problems like lack of training and limited economic resources. By grouping these into four core categories, we provide a clearer view of the leverage points that policymakers and SME support programs should prioritize.

Importantly, this study bridges the gap between those gaps and the needs of SMEs, by offering a QFD based approach. Ultimately, we argue that progress toward digital transformation does not require a perfect or complete overhaul. Even incremental changes, whether through software tools, retrofitting, or targeted upskilling, can move SMEs in the right direction. But to achieve a truly inclusive and resilient industrial future, there is an urgent need for affordable,

adaptable frameworks that reflect the diverse contexts of SMEs. Future research should continue to address these gaps and refine actionable pathways that support SMEs in this critical transition.

By answering the two research questions, this paper highlights (1) the specific barriers and expectations of SMEs in heavy freight transport, and (2) the applicability of QFD as a structured decision-making framework to support digital transformation

References

- Abdoli, S. Experimentable digital twin for virtual validation of manufacturing systems. *In Proceedings of the 2023 10th international conference on industrial engineering and applications*, pp. 91-97. 2023
- Abdoli, S. and Djukic, L., Industry 4.0 in Labor Intensive Industries, Opportunities and Challenges. *Procedia CIRP*, 136, pp.201-206. 2025.
- Collaço, F. M. d. A., Teixeira, A. C. R., Machado, P. G., Borges, R. R., Brito, T. L. F., & Mouette, D., Road Freight Transport Literature and the Achievements of the Sustainable Development Goals—A Systematic Review. *Sustainability*, 14(6), PP.3425. 2022.
- Danis, A., Rathi, M., Kumar, V.N., Roshandeivendra, D., Saklecha, S.N., Sharma, I., Winkle, C., Thayyil, N. and Abdoli, S., An innovative quality function deployment approach to manage design requirements in a team design. *Proceedings of the Design Society*, 5, pp.529-539. 2025.
- De Sousa Jabbour, A.B.L., Ndubisi, N.O. and Seles, B.M.R.P., Sustainable development in Asian manufacturing SMEs: Progress and directions. *International Journal of Production Economics*, 225, p.107567. 2020.
- Dong, C., Akram, A., Andersson, D., Arnäs, P.-O., and Stefansson, G., The impact of emerging and disruptive technologies on freight transportation in the digital era: current state and future trends, *Int. J. Logistics Manag.*, vol. 32, no. 2, pp. 386–412. 2021.
- Gamage, A., Study of Challenges in Implementing Digital Transformation in Construction Projects, *Int. J. Progressive Sci. Technol.*, vol. 30, no. 1, pp. 351–359. 2021.
- Ghobakhloo, M., M. Iranmanesh, M. Vilkas, A. Grybauskas, and A. Amran, Drivers and barriers of Industry 4.0 technology adoption among manufacturing SMEs: A systematic review and transformation roadmap, *Journal of Manufacturing Technology Management*, vol. 33, no. 6, pp. 1029–1058. 2022.
- Faisal, R. et al., The Impact of Digital Transformation on Small and Medium Enterprises (SMEs) in the USA: Opportunities and Challenges, *IRE Journals*, vol. 7, no. 6, pp. 400–407, 2023.
- Ferreira, A. J. S., Silva, F. J. G. and Rodrigues, A. M. M., Machine learning for international freight transportation management: A systematic review, *Transp. Res. Part E: Logist. Transp. Rev.*, vol. 132, pp. 1–24. 2019.
- Garetti, M. and Taisch, M., Sustainable manufacturing: trends and research challenges. *Production planning & control*, 23(2-3), pp.83-104. 2012.
- Hai, T. N., Van, Q. N., & Thi Tuyet, M. N., Digital transformation: Opportunities and challenges for leaders in the emerging countries in response to COVID-19 pandemic. *Emerging Science Journal*, 5(1), 21-36. 2021.
- Karam, A., Eltoukhy, A. E. E., Shaban, I. A., & Attia, E.-A., A Review of COVID-19-Related Literature on Freight Transport: Impacts, Mitigation Strategies, Recovery Measures, and Future Research Directions. *International Journal of Environmental Research and Public Health*, 19(19), 12287. 2022.
- Keskin, H., C. Şentürk, O. Sungur, and H. M. Kiriş, The Importance of SMEs in Developing Economies, *in Proc. 2nd Int. Symp. Sustainable Development*, Sarajevo, Bosnia and Herzegovina, Jun. 2010, pp. 183–192. 2010.
- Ji, X. and Abdoli, S., Challenges and opportunities in product life cycle management in the context of industry 4.0. *Procedia CIRP*, 119, pp.29-34. 2023.
- Mavi, R. K., Mavi, N. K., Olaru, D. Biermann, S., and Chi, S., Innovations in freight transport: a systematic literature evaluation and COVID implications, *The International Journal of Logistics Management*, vol. 33, no. 4, pp. 1157–1195. 2022.
- Mefid, K. N. M. and Ridhaningsih, F., The Impact of Digital Transformation on Supply Chain Management in Small and Medium Enterprises: A Systematic Literature Review, *Sains dan Teknologi*, vol. 17, pp. 31–42. 2022.
- Melo, I. C., Queiroz, G. A., Alves Jr., P. N., de Sousa, T. B., Yushimito, W. F. and Pereira, J., Sustainable digital transformation in small and medium enterprises (SMEs): A review on performance, *Heliyon*, vol. 9, no. 2, p. e13908. 2023.
- Lindholm, L., van der Heijden, M. J. H. and Paulsson, J. M. J., Barriers to business model innovation in the Swedish urban freight sector, *Transp. Res. Part X: Emerg. Technol.*, vol. 12, p. 100106. 2022
- Malaibari, M., Siddiqui, M., Xie, S., Bahramimianrood, B., Abdoli, S. and Djukic, L., Digital Twin as A New Approach to Data Management: A Review. *Procedia CIRP*, 128, pp.375-380. 2024.

- Nankoomar, T. and Quilling, R., Impact of Coronavirus on Digital Transformation in Private Sector Organisations in Developing Countries, *International Journal of Research in Business and Social Science*, vol. 12, no. 10, pp. 225–234. 2023.
- Philbin, S., R. Viswanathan, and A. Telukdarie, Understanding how digital transformation can enable SMEs to achieve sustainable development: A systematic literature review, *Small Business International Review*, vol. 6, no. 1, p. e473, 2022.
- Puniani, B. and Abdoli, S., Development of Capability for Integrated Smart Production-Spare Part Warehouse System for SMEs in Fast-Moving Consumer Goods sector. *Procedia CIRP*, 136, pp.159-164. 2025.
- Värzaru, A. A. and Bocean, C. G., Digital Transformation and Innovation: The Influence of Digital Technologies on Turnover from Innovation Activities and Types of Innovation, *Systems*, vol. 12, no. 9, p. 359. 2024.
- Vongchaisaree, R. and Abdoli, S., August. A Human Digital Twin Approach to Physical Hazard Management in the Manufacturing Environment: An Extensive Literature Review with a Conceptual Framework. *In IFIP International Conference on Advances in Production Management Systems*. pp. 498-512. Cham: Springer Nature Switzerland. 2025.
- Xie, S., Bahramimianrood, B., Malaibari, M., Abdoli, S. and Dietrich, F., 2024. Navigating Complexities In Closed-Loop Supply Chains: A Review Of Objectives, Uncertainties And Decision Variables. *ESSN: 2701-6277*, pp.753-765. 2024.