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Understanding twin transition dynamics in the Estonian metal manufacturing industry

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ABSTRACT

The concept of twin transition describes the simultaneous pursuit of digitalization and environmental sustainability in industry practices. This study explores the meaning of the concept within the manufacturing industry and its practical application. Although Estonia is a global leader in digital innovation, digital integration within its businesses remains limited, and environmental practices often fall short of industry standards. The paper presents findings from a qualitative study of the Estonian metal manufacturing industry, based on interviews conducted both in person and over the phone. Additionally, governmental reports, policies, and projects were analyzed to validate the findings. Findings indicate that micro enterprises associate twin transition with specific tangible objectives and prioritize survival over innovation, while small and medium enterprises weigh trade-offs between cost efficiency and market demand in their transition efforts. Since most organizations are still uncertain about the twin transition and interpret and apply the concept differently depending on their size and location, a "one size fits all" approach is ineffective. Results provide a nuanced understanding of the twin transition, highlighting its varied interpretations and applications across enterprise sizes, and offer practical recommendations for fostering industry-wide transformation. The study's key recommendations include fostering a deeper understanding of the twin transition, encouraging enterprises to share the best practices for implementation, and providing tailored support to manufacturing companies of all sizes.

1. Introduction

The concept of twin transition, which integrates digital and green transitions, is not yet an established framework among scholars. It implies the increasing acknowledgment that digitalization and sustainability must progress together to tackle global challenges. Over the last decades, substantial research has emerged on digital transformation within the manufacturing sector and on the evolution of Industry 4.0 (Ghobakhloo 2020; Rajnai and Kocsis 2018). However, increasing environmental concerns have prompted the European Commission to go further by introducing the concept of Industry 5.0 in 2020 (Fetting 2020). Industry 5.0 complements Industry 4.0 by emphasizing not only technological advancement but also environmental sustainability and the well-being of industry workers, aiming to generate value beyond economic growth and job creation while respecting planetary boundaries (European Commission 2021).

In March 2020, the European Commission introduced its industrial strategy, where the twin transition was first formally defined and promoted. The strategy aims to achieve climate neutrality and digital leadership by fostering synergies between green and digital transitions (European Commission 2020). For the manufacturing industry, the twin transition is particularly significant as it holds the potential to transform operations, reduce environmental impacts, and drive long-term competitiveness. However, the complexity of integrating digital and green goals poses significant challenges for businesses, especially small and medium-sized enterprises (SMEs) (Rupeika-Apoga and Petrovska 2022). While the literature on digital and green transformations is steadily growing, the interconnections between the two remain underexplored (Despeisse et al. 2022; El Hilali et al. 2020; Rahnama et al. 2022; Spaltini et al. 2024). For example, Chen et al. (2021) highlight that digitalization can have both positive and negative environmental impacts in manufacturing, depending on product and technology lifecycles. Vrchota et al. (2020) developed a Sustainability Green Industry 4.0 (SGI 4.0) framework to align green processes with digital technologies and sustainability goals. Similarly, Feroz et al. (2021) explored how digital transformation contributes to environmental sustainability. However, these

studies are primarily conceptual, leaving a gap in empirical evidence on how businesses, particularly SMEs, navigate the twin transition in practice.

This gap is especially pertinent in Estonia, where micro and small enterprises dominate the manufacturing sector. SMEs often face resource constraints, limited expertise, and regulatory uncertainties, making it difficult to adopt and benefit from twin transition strategies. Furthermore, laws and regulations related to the twin transition are frequently updated, requiring businesses to adapt continuously.

This paper aims to understand how Estonian SMEs understand and implement twin transition in the metal manufacturing context. We wanted to look beyond the "hype" of the e-Estonia concept by selecting a very traditional industry sector (Drechsler 2018). We address the following research questions:

RQ1: How do Estonian metal manufacturing SMEs understand the twin transition?

RQ2: How do Estonian metal manufacturing SMEs implement it in their businesses?

2. Methods

The study employs a qualitative research method. Data were collected from 22 companies in the metal manufacturing industry, representing various firm sizes. A team of three researchers, including the authors of this article, gathered empirical data by interviewing a total of 25 managers from these 22 firms. The interviews were conducted both in person and over the phone. To reach micro-sized enterprises in rural regions (Ida-Virumaa), we did phone interviews. All interviews were performed from December 2022 to May 2023. The average time of in-person interviews was 42 minutes, whereas phone interviews averaged 13 minutes each. Table 1 summarizes the data sources used.

We acknowledge the potential for bias in the interview responses. To address this, the responses were cross-validated using government reports, policies, and projects. Potential benefits, challenges faced, and necessary support for a successful twin transition within the industry sector are summarized in Table 2. Specifically, we examined initiatives and strategies related to digital transformation (e-Estonia, Estonia's Digital Agenda 2030), green transformation (Climate Policy until 2050), and industrial policy documents. Additional validation was conducted using the Estonian Machinery Industry Association research report (EML 2021). The qualitative analysis was executed using ATLAS.ti 23 software. The first quotation shows the number of documents (**X**:Y), and the second quotation shows the number of codes inside that document (X:**Y**).

3. Results

This section has two subsections devoted to each research question. We described the understanding of the concept, and then analyzed how twin transition is applied in everyday business processes.

3.1. Understanding of the twin transition

The interviews found that companies' viewpoints on the twin transition vary significantly. Firstly, we analyzed the interpretations of two meanings to answer **RQ1:** How do Estonian metal manufacturing SMEs interpret twin transition?

The meaning of "green" in the context of the metal manufacturing industry varies widely. The interview results indicate a broad spectrum of interpretations, including the use of solar panels and green electricity, waste minimization, recycling, obtaining ISO environmental management certifications, addressing political pressures, and even general skepticism toward the concept of "green." One interviewee aptly described the challenge as follows: *"It is very difficult to say [anything] about, 'green', because this scale is very wide."* (14:1). The results of the interviews were grouped into four main categories:

- Skepticism and political pressure: five out of the 22 participants expressed doubts about the feasibility of achieving complete sustainability in the metal manufacturing sector. For instance, one respondent noted: *"Maybe twin transition is real, but the green transition is unreal in the metal industry."* (10:3). Others emphasized the impracticality of zero emissions: *"Being 100% green is unclear."* (17:26). Additionally, one interviewee expressed mistrust in the accuracy of carbon footprint calculations: *"Carbon footprint calculation is just prediction, not trust."* (20:7). Another shared broader concerns about the practicality of applying green concepts to business operations: *"Everyone has heard of 'green', but nobody really knows how to apply it to business."* (17:35). The interviews also suggested a link between political developments and the implementation of environmental policies, with one respondent stating: *"The political climate in Estonia has a big impact; after four years, one party is replaced by another, and the cycle starts over with a new agenda."* (17:34).
- Importance of ISO certificates: the interviews highlighted the value of ISO certifications and other internationally recognized environmental and sustainability standards. Possessing these certifications signals a company's commitment to meeting specific environmental criteria and demonstrates its green credentials. As one participant explained: *"But we try to comply with the requirements and rules of law, to some extent, but perhaps not enough."* (3:3).

Table 1. Data sources

Interview type	Description
In-person	A total of 7 interviews with 4 medium- and 3 small-sized enterprises; roles: 5 owner-managers, 3 association members, 2 sustainability managers
By phone	A total of 15 interviews with 10 micro and 5 small-sized enterprises; roles: 12 owner-managers and 3 operations managers

- Association with solar panels and green energy: solar panels emerged as a significant symbol of green energy. However, the interviews revealed challenges related to their adoption, including high upfront costs and long payback periods. One participant recounted a negative experience: *"We waited half a year, prepared documents; it costs a million to connect, but it isn't worth it (pay-off period is long). Luckily we didn't buy solar panels."* (10:4).
- Association with recycling: recycling was identified as both an environmentally responsible practice and a cost-effective strategy in the metal industry. Many companies found using recycled metal as a raw material beneficial for efficiency and sustainability. As one interviewee explained: *"The main principle is that it is maximally waste-free, by using materials that can be recycled as much as possible, and materials that can be reused."* (14:2).

Likewise, the interview results regarding the meaning of "digital" in the context of twin transitions in the metal manufacturing industry reveal a wide range of interpretations. These interpretations range from basic operations, such as working with computers, digitally signing contracts, maintaining websites, and ordering products online, to more advanced applications, such as implementing enterprise resource planning (ERP) systems and automating production processes, including the use of robotics. Figure 1 summarizes the coding categories for "digital" and "green" as the two subsets of the twin transition.

- Paperless office: it was frequently mentioned and is closely tied to the digital public services offered by the Estonian government. This approach emphasizes reducing or eliminating paper-based processes through the adoption of digital tools and technologies. Participants highlighted the convenience of digitalization: *"In Estonia, it is very convenient that you can sign everything [digitally]. It is convenient to buy and sell without even leaving [the desk]."* (1:9).
- IoT and robotics: the integration of the Internet of Things (IoT) and robotics also featured prominently in the interviews. These technologies enable real-time data collection, monitoring, and control by connecting machines, sensors, and devices (Pizzagalli et al. 2021). One participant shared an example of their innovative use of IoT: *"We developed IoT technology that autonomously stops ships in ports without the use of anchors."* (18:3).
- Process automation: three out of 22 interview participants associated "digital" with the automation of processes in metal manufacturing. Automation involves employing advanced systems and technologies to streamline operations, enhance efficiency, and reduce human intervention. However, micro and small businesses tend to prioritize the cost-effectiveness of automation. As one participant explained: *"We had automated some parts of the work. To do more, it first needs to become worthwhile in a financial sense."* (16:3).
- ERP and computer modeling: ERP systems help companies manage and integrate critical business operations, while computer modeling enhances accuracy in predictions and analysis, aiding decision-making and operational efficiency. One interviewee described their use of computer-aided design (CAD) files: *"In designing, we use, yes, computer modeling in CAD format."* (14:4). Another participant elaborated on their custom-made software and ERP system: *"We use custom-made software, e.g., for arranging the work between engineers and production to synchronize drawings and use the ERP system, which is MS Dynamics."* (4:6).

The results suggest that individuals and companies have diverse understandings and priorities regarding digital and green transitions. This diversity underscores the importance of achieving greater clarity and consensus on the industry's specific digital and green criteria.

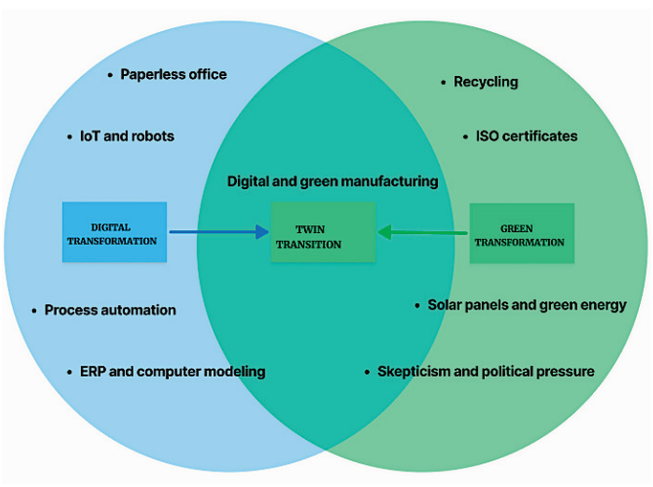

Fig. 1. Understanding of the twin transition.

3.2. Implementation of the twin transition

This section addresses **RQ2:** How do Estonian metal manufacturing SMEs implement twin transition in their businesses? Based on the interviews, companies were grouped into four categories: those who do not consider twin transition at all, those who wish to start but are unsure where to begin, those who have started implementing management optimization, and those focused on leveraging opportunities in digital and green product innovation.

- Not applicable (4 out of 22 firms): some companies reported that their processes do not require automation or digitalization to be green. This perspective suggests that, in certain cases, traditional methods and manual processes remain effective for metal manufacturing-specific needs. One participant explained: *"Since we perform our work outside, there is no need for process automation; in fact, it is not necessary for us."* (11:3). This group likely requires further exploration, as it may reflect either a lack of awareness about potential opportunities or a conclusion that twin transition is not currently cost-effective for their operations. A mindset change could encourage these companies to identify untapped potential.
- Uncertain where to start (10 out of 22 firms): a significant portion of firms expressed uncertainty about how to begin implementing green and digital initiatives. While these companies recognize the importance of sustainability and

digital technologies, barriers such as lack of knowledge, resources, or clear guidance impede their progress. One participant noted: *"We are not sure where to start because sustainability concerns have only become more prevalent in the past year. Everything must be green and sustainable."* (22:9).

- Process management (1 out of 22 firms): only one company associated twin transition with adopting lean principles in their operations. Lean management focuses on maximizing value while minimizing waste, and in this case, twin transition is seen as an extension of lean practices to incorporate environmentally friendly processes. A participant who had already embraced lean manufacturing shared: *"I initiated Lean practices two years ago. We tried to make a clean factory."* (23:31).
- Product innovation (7 out of 22 firms): several firms associated twin transition with innovation in product development. This includes introducing sustainable designs, using advanced materials, or integrating new technologies to meet evolving market demands and sustainability requirements. The focus on innovation highlights the transition from traditional product offerings to more sustainable and technologically advanced alternatives. A participant elaborated: *"How to make better products? By using less energy, working more efficiently, and producing less waste."* (22:7).

4. Conclusions

The interview results regarding the meaning of "green" and "digital" in the context of the twin transition in the metal manufacturing industry reveal diverse interpretations. As supported by academic literature, defining digital transition, green transition, and, consequently, the twin transition is inherently challenging. This complexity is similarly reflected in the industry context, where SMEs often interpret these terms through the lens of specific objects or processes (see Fig. 1). A summary of the results, including potential benefits and necessary support, is provided in Table 2.

This variation underscores the importance of raising awareness to foster a shared understanding of the potential benefits of adopting the twin transition. It is crucial to consider these diverse interpretations before making decisions about implementing twin transformations in SMEs. A "one size fits all" approach is not suitable for the current context, given the varying capacities and perspectives of businesses based on their size. Moreover, even companies recognize the importance but lack knowledge, resources, and guidance to implement changes. Companies should be aware that while green investments may temporarily limit funds for automation, successful implementation can lead to long-term efficiency gains, cost savings, and regulatory compliance. More real-world case examples of both the benefits and challenges faced by companies, highlighting improved efficiency, cost reductions, and competitive positioning alongside initial investment barriers, need to be shared and investigated. Our overall analysis indicates that companies of all sizes experience uncertainty and challenges rather than opportunities when addressing twin transition. Micro-sized enterprises, in particular, demonstrate vulnerability due to their limited resources, time, and finances. Despite often being overlooked because of their size, micro enterprises constitute a significant portion of Estonian companies and require tailored support to navigate the twin transition, otherwise they risk exiting the market.

This article emphasizes the limited empirical research on the twin transition and its practical implications across diverse contexts. Key recommendations from this study include increasing awareness and knowledge about the twin transition and providing targeted guidance and support for Estonian manufacturing enterprises. A crucial direction for future research would be to reach more companies and conduct longitudinal studies with selected companies to examine how they transition from challenges to opportunities over time

Table 2. Implementation of the twin transition: benefits and support

Category	SMEs	Potential benefits	Support needed
Not applicable	18% (4/22)	Opportunity to improve efficiency, access new markets, and achieve regulatory compliance	Awareness programs on long-term benefits; further investigation from research
Uncertain where to start	45% (10/22)	Access to new markets, regulatory compliance, and funding	Implementation guidelines, collaboration, and mentorship from green business pioneers
Digital lean	5% (1/22)	Reduced waste, improved efficiency, and cost savings	Guidance, funding support, training on best practices
Product innovation	32% (7/22)	Competitive advantage, access to green markets, and efficiency gains	R&D funding and collaboration with research institutions; tax incentives for smart and energy-efficient machinery
Recycling	23% (5/22)	Lower material costs, improved sustainability profile	Upskilling/reskilling programs on sustainable manufacturing; creating and sharing knowledge workshops on sustainable process modeling; collaborating with other companies for joint programs and funding
Paperless office	9% (2/22)	Lower operational costs, faster workflows	
ERP and computer modeling	14% (3/22)	Enhanced productivity, improved decision-making	
IoT and robotics	18% (4/22)	Increased efficiency, reduced labor costs, precision	

during the implementation period. Moreover, our findings relate to the Estonian metal manufacturing industry, but cross-sectoral comparisons regarding possible applicability to other manufacturing industries deserve further investigation.

Data availability statement

All research data are contained within the article and can be shared upon request from the authors.

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Kaksikülemineku dünaamika mõistmine Eesti metallitööstuses

Anar Abilakimova ja Merja Bauters

Kaksikületeminek tähendab tööstusharude samaaegset digiteerimise ja keskkonnasäästlikkuse poole püüdlemist. Uurimistöös käsitletakse selle mõiste tähendust töötlevas tööstuses ning selle praktilist rakendamist. Kuigi Eesti on digitaalse innovatsiooni valdkonnas üleilmne liider, on digitaalne integratsioon Eesti ettevõtetes endiselt piiratud ja keskkonnapraktikad ei vasta sageli tööstusharu standarditele. Artiklis esitatakse Eesti metallitööstuse kvalitatiivse uuringu tulemusi, mis põhinevad nii näost näkku kui ka telefoni teel tehtud intervjuudel. Tulemused näitavad, et mikroettevõtjad seostavad kaksikületeminekut konkreetsete käegakatsutavate eesmärkidega ja eelistavad ellujäämist innovatsioonile, samal ajal kui väikesed ja keskmise suurusega ettevõtted kaaluvad oma üleminekupüüdlustes kompromisse kulutõhususe ja turunõudluse vahel. Kuna enamik organisatsioone on kaksikületemineku suhtes endiselt ebakindlad ning tõlgendavad ja rakendavad seda kontseptsiooni erinevalt sõltuvalt enda suurusest ja asukohast, on universaalne lähenemisviis ebaefektiivne. Uuringutulemused annavad nüansirikka ülevaate kaksikületeminekust, tuues esile selle erinevad tõlgendused ja rakendused lähtuvalt ettevõtte suurusest, ning pakuvad praktilisi soovitusi tööstusharuülese ümberkujundamise edendamiseks. Uuringu peamised soovitused on kaksikületemineku parem mõistmine, ettevõtete julgustamine parimate rakendustavade jagamiseks ja kohandatud toe pakkumine igas suuruses tootmisettevõtetele.