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Perspectives on Digital Transformation Initiatives in the Mechanical Engineering Industry

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Abstract: Companies from the mechanical engineering industry are eager to embrace new technologies in their pursuit of a competitive advantage. However, the complete digitalization of the sector encounters limitations, as certain aspects necessitate human supervision or manual labor. This is where the concepts of Industry 4.0, Industry 5.0, and digital transformation become relevant. The aim of the research presented in this paper was to gather and extract valuable insights and lessons from the experiences of German companies in the plastic extrusion machinery sector with digital transformation (DT). Qualitative interpretative research was used, using in-depth expert interviews with C-level executives. We organized the findings into three categories: (i) DT communication initiatives, including the elimination of paper, CRM solutions, messenger services, home office, and online procurement platforms; (ii) departments and areas most involved, including accounting and procurement, sales and production, and construction; and (iii) cost–benefit perception, including positive assessment, long-term impacts, and variation from company to company. The results provide valuable insights into the progress of DT initiatives in companies operating in the pipe extrusion sector in Germany. Additionally, several DT misconceptions were identified, thereby enriching the DT misconceptions framework that has been intensely discussed in the DT literature.

Keywords: digitalization; digital business transformation; DBT; digital transformation; DT

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1. Introduction

The intricacies of the digital transformation (DT) paradigm, coupled with its connection to the fourth technological revolution, present companies with formidable challenges in their pursuit of competitiveness and leadership within their respective industries [1]. DT primarily revolves around the imperative to leverage cutting-edge technologies to maintain competitiveness in today's digital era, where goods and services are seamlessly delivered through both online and offline channels, prompting organizations to adapt and innovate [2–4]. To spearhead organizations' technological evolution, the initial imperative is to gain a firm understanding of the true dynamics of DT rather than succumbing to the allure of the buzz surrounding it [5].

In this paper, we will delve into the perspectives of C-level executives from German companies in the plastic extrusion industry regarding their involvement in DT initiatives. Our objective is to uncover valuable insights and lessons that can be gleaned from their encounters with DT. The main reason for choosing the German plastic extrusion machinery sector is that the German extrusion industry was the world leader for many years. So, it is a kind of "hidden champion"—now, it seems that many other countries are fighting for their share in the same market. Mechanical development is not growing so much anymore, and, therefore, this industry could be a good sector to start the research with, which could be later expanded to other sectors and regions.

To assist us in fulfilling the defined objective of this research, we will seek answers to three connected research questions:

RQ1: What initiatives did the executives implement to foster communication about DT?

RQ2: Which departments and areas are leading the way in DT?

RQ3: What is the efficiency (cost–benefit ratio) of the implemented DT initiatives?

To provide answers to these research questions, qualitative interpretative research was deployed, investigating the accomplished or ongoing DT initiatives in selected companies operating in the plastic extrusion industry in Germany.

The rest of the paper is structured as follows: The current state of the knowledge in regard to this topic is presented in Section 2. In Section 3, we delineate the research methodology used to gather primary data. Section 4 provides a succinct summary of the innovative insights derived from our research, while Section 5 undertakes a comparative analysis of this new knowledge in light of established concepts and findings in the existing literature. We present responses to the research questions (RQs) and explore their implications for both theory and practice while also addressing any limitations observed in our research.

2. Literature Review

The beneficial influence of DT on business performance has been well documented across a multitude of industries [6–8]. The anticipated results of digital transformation (DT) can encompass enhancements in services, processes, and relationships [9]. These improvements may manifest as increased simplicity, accessibility, quality, advantages, efficiency, speed, inclusivity, responsiveness, competitiveness, security, and transparency [2]. Furthermore, DT efforts can play a pivotal role in shaping and advancing policies and the digital landscape, whether by contributing to digital infrastructure or becoming integral components of the evolving digital ecosystem [2]. Previous literature acknowledges that DT initiatives involve a spectrum of factors, spanning backgrounds, people, businesses, and technologies [10–15]. These factors encompass the role and engagement of external digital transformation experts, the driving forces behind the transformation, and the expected outcomes. When aiming for the most significant business transformation, there is no one definitive combination of technological concepts that universally applies [1,6,16].

DT is a progressive undertaking wherein organizations amalgamate multiple novel digital technologies to attain heightened performance and maintain a sustainable competitive edge [17]. This necessitates employees to acquire the skills to effectively utilize diverse technologies, thereby enhancing their productivity and overall performance [18]. Consequently, digital literacy emerges as a pivotal requirement [19]. DT entails a foundational shift aimed at attaining enhanced performance. DT is not a project or a one-off initiative; it requires a fundamental change in organizations' perspectives, processes, and operations [20–22]. In the manufacturing industry, the concept of DT involves embracing and incorporating various novel information and communication technologies to cultivate more efficient, adaptable, nimble, and sustainable solutions for industrial systems [23]. Here, a central objective of DT is shifting away from manual and labor-intensive practices that do not add value towards digital and intelligent manufacturing setups [24].

Mechanical engineering is frequently classified under the banner of the 'traditional economy' or 'established sectors,' which experienced significant growth during the early 20th century in the era of global industrialization [25]. Companies operating in this industry have adhered to time-honored procedures for centuries and have not heavily depended on technological innovations or advancements [26]. A more suitable term for such businesses might be 'traditional enterprises,' signifying firms that adhere to conventional business methods rather than embracing state-of-the-art technologies [27]. The majority of German companies engaged in the production of plastic extrusion machinery belong to the German Mittelstand, known as the backbone of the German economy [28]. Many nations aspire to emulate the German Mittelstand due to its reputation for stability and resilience [29]. Small- and medium-sized enterprises (SMEs) are particularly coveted because they give rise to what are known as "hidden champions"—a subgroup of medium-sized companies that attain world leadership in niche products [29].

A pivotal facet of their strategy lies in maintaining a robust export presence, which bolsters their consistent and resilient performance [30]. In this export-oriented sector, achieving a competitive advantage is of paramount importance [31]. Consequently, companies within this industry are keen to adopt new technologies to gain a competitive edge. Nevertheless, the full extent of digitalization's impact on the sector is constrained, as certain aspects still require human oversight or manual labor [32]. This is where the concepts of Industry 4.0, Industry 5.0, and digital transformation come into play. There are several disruptions that can trigger the DT initiatives in these companies, which include digital disruptions, such as hacker attacks, the transformation of communication, and digital innovations, or analog disruptions, such as the COVID-19 pandemic, legislative changes, an economic crisis, or a shortage of skilled workers [33].

3. Materials and Methods

Qualitative research was chosen as appropriate for gaining insights into the experiences of executives of German companies in the plastic extrusion industry with DT. To gain firsthand insights from experts within these companies, we undertook a series of semi-structured interviews. This approach is highly regarded for its adaptability and openness, enabling an interpretative analysis of the findings and leading to a deeper and more comprehensive grasp of the research subject [34]. In this research context, the expert interviews centered on the interviewees' professional expertise, placing emphasis on their knowledge rather than their personal identity. The research sample encompassed experts from seven different companies, each boasting a rich history spanning over 80 years, all of which were identified as traditional yet innovative enterprises.

These interviews were conducted in October 2022. They followed an interview protocol prepared by both authors with a focus on adhering to a rigorous methodology that would enable both new knowledge discovery and bias elimination. One of the authors of this research has been working in this sector for 25 years. He has both the technical and market knowledge of the industry, including the contacts to the companies that were part of the research study. This knowledge, along with the extensive experience of the other author of this study with qualitative research, was used to guide the process and guarantee the outcome.

The interviews were recorded and subsequently transcribed, with interviewees being duly informed about the recording and the intention to make the results public. The questions were deliberately designed to be open-ended, affording interviewees the opportunity to provide comprehensive insights on the subject matter. The analysis of these expert interviews aimed to unearth common themes and recurring patterns in the discussions. The transcribed interviews were scrutinized using NVivo software v 1.7. Codes were formulated through the categorization of statements into distinct thematic areas, with subcodes as needed. The statements were categorized into areas that covered implementation challenges, the implementation process, and the future prospects of the companies.

Tables were created to systematically classify individual codes, with corresponding phrases being condensed to retain only the essential statements. Throughout this paper, experts are denoted as "E" followed by a consecutive number (E1, E2, and so on). The interpretation of the findings employed qualitative content analysis [35]. This process entailed the segregation of pertinent statements from less relevant ones, followed by the summarization and examination of individual interview segments to gauge their significance. Question–answer pairs were organized, and any emerging novel aspects and ideas were documented separately. Subsequently, the relevant statements were assessed in line with the research questions. When interpreting and discussing the results, the outcomes of the analysis were compared with existing studies, highlighting both commonalities and distinctions. This comparative approach contributed to the generation of fresh insights, which are presented and discussed in the subsequent sections. The data analyses were finalized in January 2023, and, subsequently, the results were processed and finalized so that they could be included in the prepared paper.

4. Results

Numerous companies have formulated and executed a range of initiatives pertaining to DT, with several of these projects having already reached completion. For many companies, undertaking such developments is imperative, as failing to do so would render them uncompetitive and unable to sustain their presence in the market. In the subsequent subsections, we will unveil the pertinent findings linked to the three research questions that we aim to address.

4.1. Communicating DT Initiatives

A significant cluster of completed initiatives pertains to the realm of communication, encompassing both internal and external aspects. A representative statement reflecting the evolution of communication due to DT was mentioned by E2: "But also in communication, we have gone through all phases; from telex to fax to e-mail to messenger". Some of the relevant statements from this category, along with their categorization, are presented in Table 1.

Table 1. Overview of DT initiatives regarding communication.

Expert	Paraphrase	Reduction	Generalization
E1	Small digitalizations such as the conversion from paper timecards to digital attendance evaluation were and are good transformations and were also implemented along the way	Even small transformations lead to great facilitations, such as digital attendance evaluation	Small DTs have a big effect
E2	But we have also been through all the communication phases; from telex to fax to e-mail to messenger	Transformation of communication technology to mails and messenger	Overall communication evolution from telex to fax to e-mail to messenger
E6	Last year at the Fakuma trade fair, we were the only exhibitor who did not show any exhibits, but only showed everything digitally	Only digital presence at the fair, no products	Analog trade fair presence only digital, no products
E6	We communicate via our Group Communication, but also in team meetings or in training sessions	Internal communication: MS Teams messenger is used	MS Teams
E6	We have had a fit-to-flight or fit-to-sale training system in place for 3 years, which means that when things change, a video or a training session is made where the staff can then dial in	Internal trainings are recorded on video where staff can watch them	Digital training system
E7	In the past, requirements were reported by hand, now there is a catalogue for clothes, hardware, software, for everything that the employees need	There is an online catalog for demand reports	Demand reports online
E7	We are now all more active on social media, which was unthinkable for us as Unicor many years ago, but now we have an account on Facebook, Instagram and LinkedIn	Increase social media activities, especially Facebook, Instagram, and LinkedIn	Increased social media activity

It can be observed that all of the companies are actively considering and have already implemented numerous DT initiatives. Some of these share commonalities, such as the shift from paper-based processes, particularly in accounting, to digital receipts and documents. Many of them also embraced digital solutions for internal communication, utilizing various messenger services and platforms to facilitate communication between team members. Video content and online tutorials have become tools for explaining and presenting information within these organizations. Consequently, for many companies, the necessity of daily office presence has diminished, with the availability of home offices as a result of these digital possibilities.

Experts reported that small-scale DT initiatives, like transitioning from paper timecards to digital time recording systems as seen in E1, have streamlined everyday work processes. E6, on the other hand, took a bold step by entirely digitalizing their trade fair presentation last year, forgoing paper and physical exhibits. Each company is engaged in digitalization and process simplification to varying degrees based on what suits them best in terms of extent and pace. This often correlates with the size and profitability of the respective company, as well as the financial resources allocated to this endeavor.

4.2. Departments and Areas Involved in DT

DT initiatives are unfolding within the company across a wide spectrum of domains. In the following section, we explore the distinct areas where changes have already been implemented or are in the planning stages. It is worth noting that some areas lend themselves more readily to DT than others. A representative statement illustrating the varied domains of DT was mentioned by E1: "We have digital archiving systems in the accounting department where we can scan all documents, which is also audit-proof". Some of the relevant statements from this category, along with their categorization, are presented in Table 2.

Table 2. Departments and areas involved in DT.

Expert	Paraphrase	Reduction	Generalization
E1	We have digital archiving systems in the accounting department where we can scan all documents, which is also audit-proof	Digital archiving systems in bookkeeping	Accountancy
E1	It started with CAD, which was the first area where we then switched to digitalization	CAD was the first area to be digitized	Construction
E6	Where there is no single source, we also use purchasing systems such as Amazon	Digital purchasing systems are used	Purchasing
E7	We also introduced a new CRM, which was another step forward for us	Advantages by implementing new CRM system	Sales
E1	We started with CAD, which was the first area where we then switched to digitalization	Introduction of a CAD system	Production

DT is being applied across a wide array of areas within companies. In certain areas, there are numerous opportunities to integrate DT and digitize processes using relatively straightforward methods, resulting in labor savings. For example, in accounting, there are abundant possibilities to revamp traditional work practices. This includes the transition from handling paper documents that are passed around and filed to processing and storing everything digitally. This shift is prevalent across most businesses, significantly reducing labor and serving as a cost-efficient approach. In many instances, there are still physical folders where receipts are stored for extended periods, largely due to legal requirements.

However, some of the companies have completely digitalized their accounting processes and employ digital archiving systems, with several having implemented this approach for multiple years.

In the realm of procurement, DT initiatives predominantly revolve around the use of online purchasing platforms. In the past, specific suppliers were associated with particular products, but nowadays, prices and products are routinely compared online, and purchases are frequently made through online retailers. These platforms can include giants like Amazon and eBay, as well as comparison portals. On the sales front, the experts have witnessed limited DT initiatives, primarily due to the complexity of this area and the scarcity of interfaces. Some companies have introduced customer relationship management (CRM) systems, aimed at systematically organizing customer relations processes. These systems store customer data and transactions in databases for ready access and diverse uses.

4.3. Cost–Benefit Ratio of DT Initiatives

DT must consistently factor in the cost–benefit aspect. Numerous DT initiatives can result in time and labor savings, subsequently reducing costs. However, it is essential to recognize that some transformations may generate more costs than benefits. A representative statement illustrating the evaluation of the cost–benefit ratio for certain digital transformations was from E2: "The cost-benefit ratio, even though it was very difficult to assess, is rather positive". Table 3 presents findings related to this area.

Table 3. Cost–benefit ratio of DT.

Expert	Paraphrase	Reduction	Generalization
E1	You also have to take into account the cost-benefit ratio, which is sometimes difficult	Consider cost–benefit expenditure	Cost–benefit effort difficult to assess
E2	Cost-benefit ratio, even though it was very difficult to assess, to be rated rather positively	Cost–benefit factor positive	Cost–benefit factor positive
E3	In most of the digitalization processes in our company it was okay, but there were also areas where I personally would say it was not okay. For example, we became more complex afterwards and had more time-consuming activities than before because of the system, which was originally planned differently	Cost–benefit factor not good everywhere; in some areas, worse than before	Cost–benefit factor not good everywhere
E7	Partly, costs could be saved through digitalization in distribution due to fewer air travels	Partial cost savings in distribution	Partial cost savings

It is essential to recognize that the cost–benefit assessment of DT initiatives varies significantly from one company to another. A DT that proves highly cost-effective and effective in one company may not yield the same benefits in another; in fact, it might even exacerbate processes rather than improve them. Consequently, each company must make individual determinations regarding DT that align best with their objectives, considering the cost–benefit factor. In most of the cases, these transformations were evaluated as having a positive impact.

In sales, the assessment was frequently positive, as substantial costs were reduced through fewer flights and business trips, especially in light of the COVID-19 pandemic, which necessitated a shift to online conferences. Digitization within machinery was also consistently regarded in a positive light, often influencing purchasing decisions. The same

sentiment applies to enhancements in workflow and digitalization within operations, which translate into time and labor savings. It is important to emphasize that the cost–benefit factor may not always be immediately apparent; often, it takes some time for the benefits of these transformations to become evident and result in noticeable cost savings. One of the biggest advantages of deploying DT is simply staying in the market and not perishing. Several experts mentioned that a more rigid cost–benefit analysis will be performed in the future, esp. when the benefits of DT materialize and can be quantified.

5. Discussion

All of the companies we interviewed have already implemented a multitude of DT initiatives, with some being proactive initiatives and others being necessitated by the imperative of ensuring the company's continued viability. These transformations have unfolded across a diverse array of areas within these companies. Certain changes are common and inevitable, such as the move away from paper-based practices in accounting and the transition from typewriters and fax machines to computers, e-mail, and messenger services. However, the progress and stage of change differ from case to case, exemplified by the distinct approaches taken in the accounting department. The idea of a paperless office is rather the side effect of a decision to fully embrace DT and its possibilities, including CRM implementation. The main drivers are the increase in process speed and the reduction in skilled workers.

A recurring focus across these cases is the elimination of paper and the endeavor to manage everything digitally. While this has proven effective in some instances, in most cases, there is still a significant amount of paper documentation that cannot be digitized entirely. This is due, in part, to various government requirements in Germany. The adoption of various customer relationship management (CRM) systems is another significant theme in these cases, aimed at optimizing relationships and interactions with existing and potential customers. Customer data and transactions are systematically stored in databases, ensuring their availability for various purposes.

Digitization has also made inroads into internal communications, with the use of messenger services and communication platforms to facilitate inter-team communication. Many companies have transitioned to a scenario where physical presence is no longer an absolute necessity for meetings and training sessions, as these can often occur online, providing flexibility in terms of timing and location. The usage of social media channels for communication has grown rapidly in recent years (RQ1).

The opportunities for buying and selling products have expanded through various platforms, especially during the COVID-19 pandemic and the associated supply chain disruptions. In each case, there is a varying degree of effort to continue the digitization and simplification of processes. The ultimate objective is to remain competitive and thrive in the global marketplace. The departments and service areas most frequently mentioned as ones driving the DT initiatives were accounting, procurement, sales, production, and construction (RQ2).

The cost–benefit assessment of DT is generally viewed as positive in most cases, although it is crucial to recognize that digital transformations can yield distinct outcomes in different cases. The time required for transformations to manifest their effects and generate benefits can be quite protracted (RQ3). Results and answers to the research questions are summarized in Figure 1.

The results presented in this paper provide valuable insights into the progress of DT initiatives in companies operating in the pipe extrusion sector in Germany. These insights can serve as an inspiration for other manufacturing companies and as a reference or benchmark to measure progress in DT. Also, several DT misconceptions were identified when talking to the company representatives, enriching the DT misconceptions framework that has been intensely discussed in the DT literature. Some of them include speaking of digital transformations (not transformation) as if these were just separate projects (the term DT projects was also mentioned a few times) or not recognizing the thin line between digital-

ization and DT. Another interesting pattern identified was some of the executives speaking of DT implementation, which again indicates its perception as a project or something that can be implemented in a certain timeframe.

Figure 1. Perspectives on DT in the mechanical engineering industry.

While strenuous efforts were made to maintain objectivity during the qualitative analysis, it is important to acknowledge that one of the authors of this study also serves as the CEO of a company that participated in the research. This author's extensive market knowledge was leveraged to gain valuable insights into the industry and its challenges. However, it is crucial to acknowledge the potential for some bias arising from this affiliation. To mitigate this, the other author actively engaged in the qualitative analysis and cross-verified the results to minimize any potential bias. The research sample encompassed 70% of all relevant companies within the industry. Nonetheless, some may perceive the sample size as relatively small, and we also recognize this as a limitation of our study.

To delineate the future research agenda, we recommend leveraging the introduced methodology and expanding the qualitative study to other industries within Germany or western Europe. Moreover, extending the research beyond this geographical region could facilitate inter-regional comparisons. We also anticipate that future research may incorporate quantitative analysis, especially if the industry under examination comprises a larger number of entities than the industry studied in the research presented in this paper.

6. Conclusions

Traditional companies in the plastic extrusion machinery industry view digital transformation (DT) as a solution to external disruptions. They understand that embracing digital transformation can enable them to adapt to shifting market dynamics and maintain their competitiveness. Nevertheless, they recognize the formidable challenges associated with implementing DT initiatives, which demand substantial investments of time, capital, and resources. One of the foremost challenges faced by these companies is the complete digitalization of their processes through the integration of advanced digital technologies and systems, as an integral component of the Industry 4.0 framework.

These companies exhibit a flexible communication culture that adapts to evolving situations rather than adhering to a standardized process. While this adaptability can be advantageous, it may also lead to occasional miscommunication or misunderstandings, potentially hindering the success of DT endeavors. Consequently, it is imperative for these companies to establish transparent communication channels and protocols to ensure alignment and unity among all stakeholders, fostering progress towards shared objectives. Working on these issues is necessary, especially in the context of the Industry 5.0 concept, which places emphasis on people.

In the foreseeable future, DT aims to address critical issues such as the scarcity of skilled labor, supply chain complexities, geopolitical uncertainties, and the impact of climate events. The overarching objective remains a sustainable international competitive edge and the generation of profits. To attain these goals, companies must harness digital

technologies to automate and enhance their operations and create novel products and services that cater to the evolving demands of their customer base.

The most prevalent misconception surrounding DT is the notion that expectations are set impossibly high and cannot be achieved. For instance, a CEO envisions a paperless office, yet printing remains a common practice, or they encourage remote work, but employees return to the office. Consequently, the anticipated impact is often exaggerated. DT frequently encounters challenges, especially in relation to older employees who may be unwilling or unable to embrace DT. Effective implementation becomes unattainable when employees resist the change. Another persistent issue pertains to data maintenance, as even the most advanced system proves futile if data are not consistently and accurately inputted. Moreover, not all aspects of an organization can be fully digitized. Some areas necessitate the expertise of qualified personnel, who are often scarce resources. These challenges underscore the need for a balanced and realistic approach to DT, acknowledging that successful implementation demands more than just advanced technology—it requires an organizational culture shift and a thorough understanding of where digital solutions are truly beneficial.

It is important to note that the outcomes and strategies presented in this context are highly specialized for the plastic extrusion machinery sector and may not be universally applicable to other industries or countries. Nevertheless, these findings can serve as a valuable reference point for similar sectors in economically advanced Western countries, offering insights for informed decision making.

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