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Trucking 4.0 – Learnings from implementing digital technologies in road freight organizations.

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Abstract

To improve efficiency, road freight organizations can digitalize processes across the freight transport chain from operations and planning to monitoring goods, equipment, and vehicles. The TRANSPORTTECH project from the Technical University of Denmark (DTU) will gather knowledge on the relevance of Industry 4.0 technology and synthesize learnings from implementation processes. This paper presents the TRANSPORTTECH project and findings from the literature. Furthermore, a pilot project case study provides first learnings of technology implementation in a freight transport chain: First for improved efficiency, road freight organizations should exchange individual software with network solutions; second, pilot projects with a limited number of partners can reduce the complexity of implementing cross-company collaboration projects; third, creative solutions to incentivize other partners are relevant to spreading the technology in the entire chain.

1. Introduction

Road freight in the EU accounts for more than three-quarters of the inland transport (Eurostat, 2022) and functions as a feeder for international air, water, and rail transport. Despite the importance of road freight transport, operations in the road freight industry remain analog and paper-based (Casanova et al., 2022; Heinbach et al., 2022; Mahajan et al., 2024). Efficient road freight handling, and hence goods transportation in general, relies on the digitalization and the implementation of new technologies, for better decision-making, enhanced collaboration, and better reactivity to changes (Speranza, 2018; Wang & Sarkis, 2021).

TRANSPORTTECH is a project of the Technical University of Denmark (DTU) aiming to improve efficient road freight transport by implementing Industry 4.0 technologies in Danish road freight organizations. The project has two main objectives: a) Share knowledge from experienced faculty members with freight organizations by analyzing the potential for optimization and identifying suitable Industry 4.0 technologies to implement; b) A PhD project that translates the learnings about technology implementation from these project internal cases as well as from project external cases into academic knowledge.

1.1. TRANSPORTTECH project

TRANSPORTTECH helps Danish freight organizations implement Industry 4.0 technologies through a structured, hands-on approach. Organizations start with an initial analysis to identify optimization or development opportunities and assess technological readiness. In the next phase, specific solutions such as digital documentation, predictive maintenance, and IoT-based monitoring are tailored to company needs. Depending on the organization's wishes, a pilot implementation can be included, which allows businesses to test technologies in a controlled setting, ensuring practical feasibility. Following successful pilots, full-scale implementation is supported with expert guidance from DTU Engineering Technology. The final phase focuses on documenting the best practices and scaling solutions across the sector. By following this step-by-step process, companies gain experience and confidence in integrating digital tools that improve efficiency, sustainability, and competitiveness.

1.2. PhD project

The PhD project, part of the larger TRANSPORTTECH project, aims to understand the under-researched field of Industry 4.0 technology implementation in road freight. While the larger project aims at identifying suitable technologies, the PhD focuses on the organizational context. According to the literature, technology implementation is more successful when organizational factors are considered (Shim & Min, 2002). The PhD project contributes to the general body of knowledge in the freight transport domain by answering a) how small and medium-sized road freight organizations implement Industry 4.0 technologies and b) how and why different organizational factors influence successful Industry 4.0 implementation. Furthermore, an essential component of the PhD project is the dissemination of success stories and experiences to the industry.

The main method applied in the PhD project is case study research. The underexplored nature of Industry 4.0 implementation in road freight lends itself to an explorative method, allowing to study the natural setting and understand the complexity and nature of the phenomena (Meredith, 1998). The cases are selected from the TRANSPORTTECH project in combination with project external cases, where organizations implement technologies without university influence. Combining the two types of cases provides rich documentation for the project's internal cases and a more realistic picture of the implementation for the external cases. "Thick data" consisting of observations, interviews, project documentation, and other sources, is used to analyze the implementation process in the organizations.

2. Theoretical background

Industry 4.0 is a transformation through digitalization and automation (Nikitas et al., 2020) to optimize supply chain processes, activities, and relationships (Frederico et al., 2019). Industry 4.0 technologies range from hardware to software-oriented and from firm-level to supply-chain-level technologies (Culot et al., 2020). While some of the Industry 4.0 technologies enable gathering and understanding of information, other Industry 4.0 technologies help to improve the automation process (Govindan et al., 2022).

Industry 4.0 technologies can be implemented throughout the freight transport process, from operations, planning, and monitoring, as illustrated with examples in Figure 1. The technologies enable data-driven decision-making (Speranza, 2018), and improve general efficiency, effectiveness, and sustainability (Modica et al., 2023) throughout the freight transport chain. Despite recent literature on possible applications and potential benefits in logistic processes (e.g., Govindan et al., 2022; Wong et al., 2024), the use in practice and hence, related implementation research, are scarce.



Figure 1: Examples of Industry 4.0 applications in road freight

“Implementation includes any processes undertaken to institutionalize a new technology as a stable part of the organization” (Griffith, 1996). The implementation process can be divided into different stages; most implementation theories start with the knowledge generation and end with the routinization in the organization or the diffusion of the technology in the whole supply chain (e.g. Cummings & Worley, 1998; Rogers, 1995). Each implementation stage entails different challenges that need to be viewed separately. The first barrier is often the limited resources to invest money, followed by the lack of technical skills for the implementation and operations (Molero et al., 2019). After the implementation, end-users (e.g. truck drivers) need to accept using the new technology to generate the desired benefits of the implementation (e.g., Castritius et al., 2020; de Winter et al., 2024). Limited implementation experiences make the diffusion of innovations in the entire freight transport chain difficult.

3. First learnings from a pilot project

The first learnings from Industry 4.0 implementation are illustrated by a case study of a pilot project. The pilot project was initiated by a transportation hub in collaboration with a technology supplier, aiming at reducing paper-based processes throughout the complete freight transport chain. The main partners next to the transportation hub and the technology supplier are a freight forwarder, a road carrier (trucking company), a freight handling organization, as well as a trade organization. The transportation hub pushed for a digital platform that is simple to implement for all involved partners. A standardized solution reduces the financial and knowledge barriers often faced by small and medium-sized organizations (Molero et al., 2019) and a pilot project can showcase the benefits of technologies, and address challenges, on a smaller scale to minimize the risks involved with the implementation (Zhou et al., 2024). The pilot project is an ideal case study to understand the implementation process throughout the whole freight transport chain. The data from this case study was gathered from an interview with the technology supplier and various project documents.

The aim of the digital platform is to improve the data quality (from 60% to 95% accuracy), to stay compliant with digital and automated authority requirements, and to improve resource allocation and time planning for freight forwarders, road carriers, freight handlers, and the transportation hub. One of the main challenges highlighted in the interview is the traditional way the industry views digitalizing processes: *“The industry is still thinking in papers; they are still thinking in the old environment. If you use my portal [...], you can upload your documents [...] and then somebody else on the other end can download some documents, but that’s not being digital at all”*. This is why the pilot project aims at implementing a standardized solution that enables implementing end-to-end processes in a network rather than a company-to-company system to transfer documents. A user-friendly step-by-step guide provides access to the platform within less than a day. This

enables small organizations with limited resources, such as road carriers and small freight forwarders, to easily access this platform.

For the pilot, the transportation hub selected a single organization for each partner in the freight transport chain. Choosing a single organization simplifies project management, ensures communication, and reduces complexity. Including the complete freight transport chain allows the partners involved to understand if the operations function seamlessly across the different freight transport processes and allows for knowledge sharing between the partners.

After a successful pilot project implementation, it will be essential to motivate other organizations to utilize the platform. In this case, other organizations will be incentivized through priority off-loading times at the transportation hub, generating a relative advantage to the carriers and freight forwarders that join the platform.

4. Conclusion

The purpose of the TRANSPORTTECH project is to share knowledge on Industry 4.0 with road freight organizations, while at the same time learning and studying the technology implementation process in real-case scenarios. Many of the cases are still in their early stages, with no finalized results available yet. Therefore, relevant literature and an external case study, which is examined as part of the PhD project, provide some first insights on the topic. Literature shows different Industry 4.0 applications within road freight operations, planning, and monitoring, and shows the potential benefits of implementing such technologies. In the implementation process, it is essential to take organizational factors into account, rather than solely focusing on technology features. From the case study, we learn that the freight industry's definition of digitalization often focuses on digitizing papers rather than digitalizing processes. In the context of digitalization, it is important to provide network solutions over individual company solutions. Since such network solutions can be complex, a pilot project can simplify the implementation by reducing the number of partners involved. Finally, to push the technologies in the whole network, incentives to join such a platform should be provided.

5. References

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