

Managerial Digital Competencies and Process Integration as Drivers of Digital Transformation in Transport Enterprises: Evidence from Central Europe Using PLS-SEM

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Abstract

Research background: Digital transformation has become a key determinant of competitiveness for transport enterprises operating in an environment characterised by rapid technological change. Although this topic has attracted considerable attention in the general literature, the transport sector remains relatively underexplored from the perspective of empirical research on digital transformation. Sector-specific characteristics—such as high operational complexity, dependence on real-time data, regulatory constraints, and stringent safety requirements—create the need for a targeted and integrated research approach.

Purpose of the article: The aim of this article is to analyse the key managerial, technological, performance-related, and process-related factors influencing the level of actual digital transformation in transport enterprises. The study focuses in particular on the role of managerial digital competencies, knowledge of digital infrastructure, business process integration, and the management of digital performance, including cybersecurity.

Methods: The empirical part of the study is based on an international questionnaire survey conducted among managers and professionals employed in transport enterprises across Central Europe. The data were analysed using Partial Least Squares Structural Equation Modelling (PLS-SEM), which enables the testing of complex relationships among latent variables and is particularly suitable for prediction-oriented research.

Findings & value added: The results confirm that digital transformation in the transport sector is significantly influenced by managerial digital competencies and the level of understanding of digital technologies. The findings further indicate that the integration of processes and the systematic monitoring of performance metrics, including cybersecurity indicators, play a crucial role in achieving higher levels of digital maturity. The main contribution of the article lies in the development of an integrated competency-based model of digital transformation specifically tailored to the transport sector, which extends existing theory and provides practically relevant implications for managerial decision-making.

Keywords

Digital transformation; Transport enterprises; Digital readiness; Managerial digital competencies; Process integration; PLS-SEM; Central Europe.



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Introduction

Digitalization and digital transformation have become among the most prominent topics in both academic and applied research in recent years, as they fundamentally influence firms' competitiveness, operational efficiency, and ability to adapt to a dynamically changing economic environment. Rapid advances in digital technologies, increasing data availability, and growing pressure on process efficiency are compelling enterprises across industries to reconsider traditional approaches to management and value creation.

Despite the extensive body of academic research devoted to digital transformation (Saeedikiya, M., Salunke, S., & Kowalkiewicz, M., 2024, Ubiparipovic, B., Matkovic, P., & Pavlicevic, V., 2022, Zhang, X., Xu, Y. Y., & Ma, L., 2023) a number of unresolved issues remain, particularly with respect to sector-specific applications and the empirical validation of complex relationships among key determinants of digital transformation (Tolkachev et al., 2020).

A considerable number of representative studies focus either on broad conceptual discussions of digital transformation (e.g., Szopa & Cyplik, 2020, Almunawar, M. N., Anshari, M., De Pablos, P. O., & Fauzi, A. M., 2025) or on narrowly defined technological aspects, such as information systems adoption, automation, or data utilization (e.g., Papavasiliou, S., Gorod, A., & Reaiche, C., 2024, Tsakalerou, M., Batyrbek, B., Bekzhan, A., Askerova, S., Khamitova, A., & Mobayo, J. O., 2025), while largely neglecting the managerial and process-related mechanisms through which digital transformation is actually enacted within organizations. As a result, digital transformation is frequently treated as a technological outcome rather than as an organizational process driven by strategic decision-making, capability development, and process integration.

Moreover, much of the empirical literature addressing digitalization in transport enterprises relies on descriptive analyses or simplified analytical frameworks that fail to capture the multidimensional and interdependent nature of digital transformation (Fedorko, G., Molnar, V., & Michalik, P., 2023, Kahveci, E., 2025, Bhavsar, V., Samanta, P. K., Malsane, S., & Deepak, M. D., 2025). Even studies (Tubis, A. A., 2025) that acknowledge organizational or strategic dimensions tend to examine these factors in isolation, without integrating managerial digital competencies, technological prerequisites, process integration, and performance management into a coherent explanatory model. Consequently, the existing evidence provides only limited insight into why similar technological investments lead to fundamentally different transformation outcomes across firms, and why digital initiatives often remain fragmented or fail to generate systemic change, particularly in highly regulated and operationally complex environments such as transport (Pyankova, S. G., & Zakolyukina, E. S., 2024, Ezgeta, D., Causevic, S., & Mehanovic, M., 2023).

This research gap limits understanding of the mechanisms underlying digital transformation in transport enterprises and reduces the applicability of existing findings for managerial practice.

The objective of this article is therefore to analyse the key managerial, technological, process-related, and performance-related factors influencing the level of actual digital transformation in transport enterprises.

The contribution of the present study lies in the development of an integrated conceptual model of digital transformation that reflects the specific characteristics of the transport sector and links technological, managerial, and process dimensions within a unified analytical framework. In doing so, the study extends existing theoretical knowledge by introducing a sector-specific perspective, while simultaneously providing practically applicable insights for the strategic management of digital transformation in transport enterprises.

The empirical part of the research is based on a questionnaire survey conducted among managers and professionals working in transport enterprises in four Central European countries. Data analysis is performed using Partial Least Squares Structural Equation Modelling (PLS-SEM), which enables the testing of complex relationships between latent variables and is suitable for exploratory and prediction-oriented research.

The structure of the article is as follows. Following the introduction, a literature review focusing on digital transformation, digital literacy, and the specific characteristics of the transport sector is presented. Based on the literature review and the research objectives, research hypotheses are formulated and an original conceptual model is developed. The next section describes the research methodology and design. The results of the data analysis are then presented and subsequently discussed in relation to existing literature. The article concludes with a summary of the main findings, the research contributions, its limitations, and recommendations for future research and managerial practice.

Theoretical Background and Hypotheses Development

Digital Transformation as a Multidimensional Phenomenon

Digital transformation of enterprises has become a key topic in contemporary academic literature, closely linked to structural changes in the global economy and the increasing role of digital technologies across all economic sectors (Szopa & Cyplik, 2020, Wang, H., & Wang, S., 2023, Firk, S., Hennig, J. C., Meier, J., & Wolff, M., 2025). Scholars widely agree that digital transformation cannot be reduced to the mere implementation of information and communication technologies; rather, it represents a profound and long-term process encompassing changes in corporate strategy, organizational structures, business processes, employee

competencies, and organizational culture (Ellström et al., 2022, Oberlaender, A. M., Karnebogen, P., Roevekamp, P., Roeglinger, M., & Leidner, D., 2025, Wurm, B., Matt, C., Benlian, A., & Hess, T., 2025).

Despite the growing body of research addressing individual aspects of digital transformation, the literature still lacks comprehensive empirical models that systematically integrate managerial competencies, technological infrastructure, process integration, and transformation outcomes (e.g. Liu, X., Lv, B., & Zhou, Q., 2024, Urban, I., & Plattfaut, R., 2025). This shortcoming is particularly pronounced in the transport sector, where empirical research on digital transformation remains relatively limited (Tolkachev et al., 2020, & Qin, R., 2025). This gap creates opportunities for the application of prediction-oriented analytical approaches, such as Partial Least Squares Structural Equation Modelling (PLS-SEM), which allow for the analysis of complex interrelationships among latent constructs and contribute to further theoretical development in the field of digital transformation.

These characteristics suggest that digital transformation in transport cannot be adequately explained by a single factor approach but rather requires an integrated theoretical framework capturing managerial, technological, and process related mechanisms simultaneously. The present study builds on this premise and develops an integrated model that explicitly links managerial digital competencies, technological prerequisites, process integration, and performance management to the level of actual digital transformation.

Managerial digital competencies and digital transformation in transport enterprises

Management plays a crucial role in the digital transformation of transport enterprises. Numerous studies emphasize that managerial digital competencies constitute a key determinant of successful transformation processes (Firk et al., 2025). These competencies extend beyond technical knowledge and include, in particular, the ability to understand the strategic implications of digitalization, integrate digital data into decision-making processes, and effectively manage organizational change (Masłowski et al., 2020).

The concept of Human Digital Transformation Readiness highlights the importance of managerial mindset, openness to innovation, and active support of employees throughout digital change initiatives (Gupta et al., 2022). Without strong managerial involvement (Luo, T., Qu, J., & Cheng, S., 2025, Fang, X., & Liu, M., 2024, Succurro, M., & Donati, C., 2025), digitalization efforts often remain fragmented and confined to isolated technological projects with limited systemic impact. In transport enterprises (Steiner, S., 2009, Utomo, A. A., Maulida, M., & Musa, S., 2023) —where digital initiatives typically require close coordination across operations, IT functions, and external partners—managerial capabilities can therefore be expected to play a decisive role in achieving actual digital transformation.

Based on these arguments, the following hypothesis is formulated:

H1. *Managerial digital competencies are positively associated with the level of actual digital transformation in transport enterprises.*

Technological prerequisites and digital transformation

Technological prerequisites represent the foundational technological conditions that enable digital initiatives, including adequate IT infrastructure, data availability and quality, and system reliability. A distinctive feature of the transport sector is its strong dependence on operational continuity and reliability. Failures of information systems, erroneous data inputs, or breakdowns of digital solutions can have immediate economic and safety-related consequences.

Accordingly, the literature emphasizes the importance of robust digital systems, backup solutions, and systematic management of technological risks as integral components of digital transformation in transport enterprises (Fedorko et al., 2023). At the same time, technological infrastructure constitutes a fundamental dimension of digital transformation. Research distinguishes between software and hardware components of infrastructure and points out that mere availability of technologies does not guarantee their effective utilization (Li & Sun, 2025). Empirical studies show that firms often possess advanced technologies that remain underutilized due to insufficient knowledge, weak process integration, or the absence of a clear digital strategy (Brown & Brown, 2019, Sciuk, C., Engert, S., Gierlich-Joas, M., & Hess, T., 2025).

In the transport sector, technological infrastructure is further characterized by high operational complexity and stringent reliability requirements, which place increased demands on both managerial and employee competencies (Steiner, 2009, Wurm, B., Matt, C., Benlian, A., & Hess, T., 2025). Based on these considerations, the following hypothesis is proposed:

H2. *Technological prerequisites of digitalization are positively associated with the level of actual digital transformation in transport enterprises.*

Process prerequisites and digital transformation

The process dimension of digital transformation is widely regarded in the literature as one of the primary sources of value creation through digitalization (Deiss, 2000). Scholars consistently argue that the digitalization of isolated processes does not generate sustainable competitive advantages unless it is accompanied by their integration across organizational functions (Li et al., 2018; Krajčík, 2021; Krajčík, 2022). Integrated digital

processes facilitate improved information flows, greater transparency, and faster organizational responses to environmental changes. Empirical research further confirms that the degree of process integration is closely related to the level of digital maturity of enterprises (Kaganer et al., 2023).

The importance of process integration is particularly evident in transport enterprises (Lazur, J., Hynek, J., & Hruska, T., 2024), where operational processes are highly interdependent and rely on continuous data exchange in real time (Rohovyi, O., Samsonkin, V., Yurchenko, O., & Bureika, G., 2025). Fragmented or poorly integrated digital processes may even exacerbate operational complexity rather than reduce it. Consequently (Oeschger, G., Caulfield, B., & Carroll, P., 2025), process integration represents a critical link between digital ambitions and realized transformation outcomes.

Based on the findings of the mentioned studies, the following hypothesis is formulated:

H3. *Process prerequisites of digitalization are positively and significantly associated with the level of actual digital transformation in transport enterprises.*

Performance prerequisites of digital transformation

An additional important area of research concerns the measurement and management of digital transformation performance. Performance metrics serve not only to evaluate the return on investment in digital technologies, but also as instruments for managerial control and strategic decision-making (Zakharov et al., 2022). Organizations that systematically monitor the performance of digital initiatives tend to exhibit higher levels of digital maturity and greater adaptive capacity.

At the same time, the importance of cybersecurity and data protection has increased substantially, as these aspects are increasingly viewed as integral components of digital transformation (Zhang et al., 2023). Inadequate management of cyber risks can undermine trust in digital technologies and significantly hinder transformation processes. The literature also highlights a lack of empirical studies examining the relationship between digital transformation management and performance measurement in the transport sector (Matushkina et al., 2022).

Digital transformation in transport is closely intertwined with the regulatory environment. Transport enterprises are subject to strict requirements related to safety, data protection, labor conditions, and environmental standards (Fedorko et al., 2023). While digital technologies are often deployed as tools to meet regulatory requirements, they simultaneously generate new demands for governance, reporting, and control. This increases the importance of managerial digital competencies and the ability to strategically align technological innovation with legislative constraints (Pyankova & Zakolyukina, 2024; Gnap et al., 2019).

In recent years, the linkage between digital transformation and sustainability has also gained prominence in the transport sector. Digital technologies enable route optimization, fuel consumption reduction, emissions monitoring, and more efficient resource utilization (Durand et al., 2023). Empirical studies indicate that enterprises capable of aligning digital innovation with environmental objectives achieve higher operational efficiency and more favorable perceptions among customers and regulators (Ceniga & Sukalova, 2013; Fedorko et al., 2023).

Based on these arguments, the following hypothesis is proposed:

H4. *Managerial evaluation of processes essential for digitalization governance significantly influences the monitoring of digital transformation performance metrics in transport enterprises, including cybersecurity and data protection indicators.*

Research gap and methodological justification

The formulation of four hypotheses in this study is not arbitrary, but a direct consequence of the theoretical grounding of the research, the structure of the conceptual model, and the methodological requirements of PLS-SEM. From a methodological perspective, a clear gap can be identified in the limited use of prediction-oriented analytical approaches, such as PLS-SEM, in empirical research on digital transformation in transport. Most existing studies rely on descriptive analyses (Hair et al., 2014), case studies (Vaithilingam et al., 2024), or simple regression models (Kurtaliqi et al., 2024; Richter et al., 2022; Nitzl, 2016), which are not capable of capturing the complex and interrelated relationships among latent constructs.

The absence of comprehensive empirical models constrains a deeper understanding of the mechanisms driving digital transformation in the transport sector. Consequently, there remains a clear research gap in integrative and empirically validated modelling approaches that systematically link managerial digital competencies, technological infrastructure, process integration, digital literacy, and performance outcomes of digital transformation. Addressing this gap provides a foundation for advancing digital transformation theory while simultaneously offering practically relevant insights for the management of transport enterprises.

By integrating these four core mechanisms into a single conceptual framework and empirically testing them using PLS-SEM, the study responds directly to calls for more coherent and theory-driven models of digital transformation, particularly in sector specific contexts such as transport. This integrated approach provides a clearer theoretical foundation for the empirical analysis and addresses the fragmentation observed in prior research.

Research Methods

The proposed original conceptual model provides the theoretical foundation of this study by defining the key latent constructs and the directional relationships among them (Bayaga & Kyobe, 2021). The model is derived from an extensive review of relevant academic literature (Becker et al., 2023) and reflects the assumed causal mechanisms underlying digital transformation in transport enterprises.

At this stage, the model serves as a theory-driven representation guiding hypothesis development and does not yet incorporate any statistical estimates. Partial Least Squares Structural Equation Modelling (PLS-SEM) is employed as the main analytical method. PLS-SEM is a variance-based structural equation modelling approach that applies ordinary least squares (OLS) estimation procedures to estimate model parameters (Henseler et al., 2025). These estimation procedures are designed to maximise the coefficients of determination (R^2) of endogenous latent constructs. For this reason, PLS-SEM is considered particularly suitable for prediction-oriented research, the explanation of variance, and theory development, rather than for purely confirmatory testing of established theories (Hair et al., 2019).

The method enables the quantification of explained variance through R^2 values and allows for the assessment of the statistical significance of structural relationships between latent constructs (Magno et al., 2024). The evaluation of reflective measurement models has been extensively discussed in the literature (Cepeda et al., 2024; Henseler et al., 2025; Leong et al., 2025). Moreover, the empirical model enables the simultaneous assessment of the measurement model—verifying the reliability and validity of the constructs—and the structural model, which evaluates the predictive power and explanatory relevance of the hypothesised relationships (Kock, 2017; Sarstedt et al., 2014).

Data collection and conceptual model

To obtain a sufficient amount of data for the empirical PLS-SEM analysis, a dedicated questionnaire was developed by the authors. The introductory section of the questionnaire (questions Q1–Q6) focuses on the contextual and structural characteristics of the respondents and their enterprises. These questions serve to describe the research sample and to establish the necessary framework for interpreting the subsequent analytical results. A detailed description of the individual questions is provided in Table 1.

Table 1: Questions

Question	Question description	Variable type	Purpose in analysis
Q1	Length of respondent's professional experience in the field	Ordinal (categorical)	Sample description
Q2	Company size measured by number of employees	Ordinal (categorical)	Sample description
Q3	Age of the company (years since establishment)	Ordinal (categorical)	Sample description
Q4	Economic size of the company (total assets)	Ordinal (categorical)	Sample description
Q5	Industry sectors of the company's customers	Nominal (multiple responses)	Contextual characterization
Q6	Geographical and market scope of business activities	Nominal	Contextual characterization

The conceptual model developed by the authors represents a novel conceptual foundation of the study and defines the main latent constructs, their theoretical grounding, and the presumed relationships among them. In general, a conceptual model can be understood as a graphical and theoretical representation of key latent constructs, their causal relationships, and the direction of effects between them (Bayaga & Kyobe, 2021; Meng, M., Fan, S., Lei, J., & Feng, Y., 2025).

However, digital transformation is widely recognised in contemporary literature as a multidimensional phenomenon that cannot be adequately explained by a single causal relationship (Szopa & Cyplik, 2020). Each dimension represents a theoretically distinct mechanism of influence and therefore requires a separate hypothesis. Collapsing these dimensions into a smaller number of hypotheses would result in theoretical oversimplification and would not be consistent with the current state of knowledge.

The prediction-oriented approach adopted in this study, together with the newly developed conceptual model, enables the testing of multiple parallel causal relationships, the assessment of the relative strength of individual predictors, and the explanation of variance in the endogenous construct through multiple independent constructs. Consequently, when designing the model based on the four key hypotheses (defined in the previous chapter), it was necessary to extend the model with additional constructs that are essential for fully exploiting the potential of the method and for meaningful interpretation of the model's predictive power.

Within this study, the constructs were organised into thematically coherent domains, with their indicators representing manifestations of the underlying latent constructs.

Q7 captures the extent of software tool utilisation within the enterprise as a fundamental pillar of digitalisation.

Q8 represents the human dimension of digitalisation, particularly employees' digital skills, attitudes, and readiness to operate in a digitalised environment.

Q10 measures the level of knowledge and experience of specific digital technologies.

Q11 reflects the perceived importance of hardware infrastructure required for enterprise digitalisation.

Q12 captures the actual level of hardware infrastructure implementation within the enterprise. In contrast to Q11, which focuses on perceived importance, Q12 evaluates the actual state of implementation of individual hardware components.

Q13 focuses on the theoretical and normative perception of the necessity of digitalising operational processes and their integration.

Q14 evaluates the actual state of operational process digitalisation and integration within the enterprise.

Q15 captures the economic, operational, and psychological impacts of digitalisation, including both benefits and risks.

Q16 represents managerial and strategic aspects of digitalisation governance.

Q17 captures the relationship between digitalisation and environmental sustainability.

Q18 evaluates the extent to which digitalisation-related performance indicators (KPIs) are monitored and assessed.

Q19 captures the level of cybersecurity management and data protection within the enterprise.

A more detailed description of the individual construct items is provided in Table 2.

Table 2: Constructs

Construct	Construct Name	Definition	Items
Q7	Software infrastructure of digitalization	Extent of use of software applications supporting digitalized operations.	Office systems; Database systems; ERP; CRM; AI systems; Management systems; Communication tools; TMS; Telematics; Fleet management; Analytics
Q8	Human capital and digital competences	Digital skills, attitudes, readiness and perceptions of employees toward digitalization.	Ability to work digitally; Attitudes; Concerns; Management support; Innovation; Employability
Q10	Awareness of digital technologies	Level of knowledge and use of digital technologies in transport and logistics.	Cloud; Big data; IoT; AI; Robotics; TMS; FMS; WMS; ESG monitoring
Q11	Hardware prerequisites – importance	Perceived importance of hardware infrastructure for digitalization.	Servers; Networks; Security; On-board units; GPS; Sensors; Mobile devices
Q12	Hardware prerequisites – current state	Actual level of hardware infrastructure implemented in the company.	Servers; Networks; Security; Telematics; Devices
Q13	Process and integration prerequisites	Normative perception of the need for digitalized and integrated processes.	Process digitalization; System integration; Data usage; Training; Innovation culture
Q14	Level of process digitalization	Actual level of digitalization and integration of processes.	Digital dispatching; Billing; Maintenance; Data optimization
Q15	Benefits and risks of digitalization	Perceived benefits, costs, risks and impacts of digitalization.	Efficiency; Costs; Profitability; Risks; Investments
Q16	Digitalization management and strategy	Strategic and managerial governance of digital transformation.	Digital strategy; IT management; Automation; AI; Change management
Q17	Digitalization and sustainability	Environmental impacts and sustainability aspects of digitalization.	Emissions; Resources; Waste reduction; Green investments
Q18	Performance metrics of digitalization	Monitoring and evaluation of performance indicators related to digitalization.	KPI definition; ROI; Evaluation; Communication

Q19	Cybersecurity and data protection	Level of cybersecurity management and data protection.	Security policies; Training; MFA; Backups; Incident response
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The conceptual model of the study is derived from the theoretical framework and depicts the assumed relationships among the latent constructs. The model distinguishes between predictor and outcome variables, whereby constructs Q8, Q11, Q13, Q16, and Q17 are considered key determinants of the outcome constructs Q7, Q12, Q14, and Q19.

Figure 1 graphically illustrates the conceptual model developed in this study. It presents the relationships among the latent constructs derived from the theoretical framework and specifies the directionality of effects from exogenous constructs to endogenous constructs, serving as the basis for hypothesis formulation. At this stage, the conceptual model represents a theory-driven abstraction and does not include any statistical estimates. The subsequently applied empirical PLS-SEM model constitutes a direct operationalisation of the conceptual framework presented in Figure 1. The latent constructs, structural paths, and their directional relationships are specified in the empirical model exactly as depicted in the figure, thereby ensuring consistency between the theoretical assumptions and the empirical analysis. Figure 1 thus functions as the structural blueprint of the empirical model.

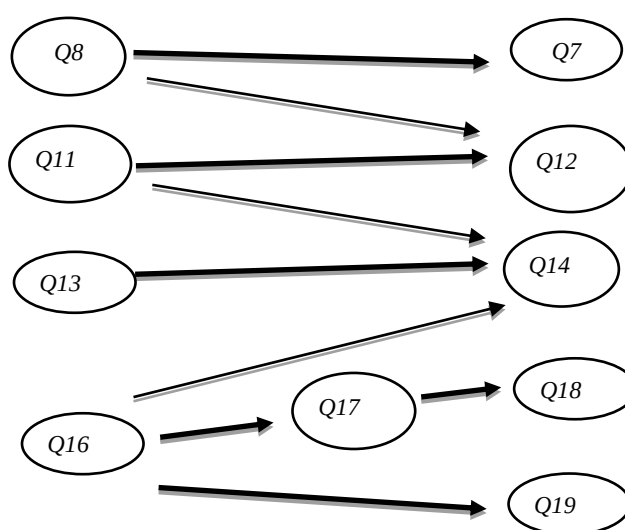


Figure 1: Graphical representation of the conceptual model

Results was conducted using a direct survey method. The first preparatory phase focused on telephone interviews and pilot testing of the questionnaire and took place between February and April 2025. Based on data from the Czech Statistical Office and statistics on firm numbers and sizes in the industry category (CZ-NACE “B–E”), a decision was made to ensure equal representation of micro-enterprises (1–9 employees), small enterprises (10–49 employees), and medium-sized enterprises (50–249 employees). Each respondent category included 20 respondents. Following the evaluation of the pilot survey, formal adjustments and minor revisions to the wording of questionnaire items were implemented.

The second phase of data collection was conducted between May and September 2025 and involved cooperation with the external research agency MNFORCE. The respondent sample was selected based on proportional representation of small and medium-sized enterprises across four countries—the Czech Republic, Poland, Hungary, and Slovakia—using data from the Cribis database and the agency’s internal respondent database. An online questionnaire was generated and distributed to randomly selected SMEs via email invitations. Data collection was carried out through the agency’s online platform as a direct B2B survey targeting decision-makers in transport and logistics enterprises.

The target sample of 600 respondents (with equal representation from all four countries) was approached using a multi-layered targeting strategy based on a panel of tagged respondents. Panel participants were classified according to professional characteristics (industry, seniority, job position), supplemented by a socio-economic filter prioritizing respondents with above-average income typical of managerial and decision-making roles. In addition, screening questions at the beginning of the questionnaire were used to verify that respondents were employed in transport-related enterprises and held relevant positions (entrepreneurs, owner, director, or middle- to senior-level manager). In total, the sampling frame comprised 2,055 transport and logistics enterprises. A total of 600 completed questionnaires were collected (150 from each country: the Czech Republic, Poland, Hungary, and Slovakia). The detailed structure of the respondent sample is presented in Table 3.

Table 3: Structure of respondents

	N
Micro	280
Small& medium	320
Male	410
Female	190
Work exp Up to 10 years	320
More than 10 years	180
Education Less than bachelors'	90
Bachelors and more	510
Total	600

Questions Q1–Q6 were not included in either the measurement model or the structural model of the PLS-SEM analysis, as their primary purpose is descriptive and contextual rather than the measurement of latent constructs. These items capture characteristics of the respondents and their organizations, such as professional experience, firm size and age, economic strength, industry orientation, and geographic scope of operations. They therefore do not represent indicators of theoretically defined latent variables but rather exogenous descriptive variables. It should also be emphasized that the objective of the PLS-SEM analysis in this study is to test and further develop a theoretical model of relationships among latent variables, rather than to explain variance based on structural or demographic characteristics of respondents. In line with methodological recommendations (e.g., Hair et al., 2022; Henseler et al., 2025), questions Q1–Q6 are thus used exclusively for describing the research sample and for providing contextual support for the interpretation of the main analytical findings.

The remaining questionnaire items are fully aligned with the conceptual model and the proposed constructs and operationalize the digitalization of transport enterprises as a multidimensional system encompassing technological infrastructure (Q7, Q11, Q12), human capital (Q8), processes and integration (Q13, Q14), strategic management (Q16), performance and security (Q18, Q19), and the environmental dimension (Q17). For questions Q7–Q19, a five-point Likert scale was employed to measure respondents' agreement with the statements, ranging from "1 = strongly disagree" to "5 = strongly agree".

The data analysis was conducted using the statistical software packages SPSS (www.spss.com) and JASP (<https://jasp-stats.org/>). The following section presents the statistical findings obtained through the application of the proposed conceptual model of constructs and the reflective PLS-SEM measurement model. In accordance with the methodological guidelines provided by Bayaga, A. & and Kyobe, M. (2021), appropriate statistical measures were employed for the analytical processing of the data. The R^2 values obtained are promising (see Table 3). The variability of the endogenous latent variables is substantially (all R^2 are higher than 0.5...) described (explained) by the exogenous latent variables. The R^2 measures the variance, which is explained in each of the endogenous constructs and is therefore a measure of the model's explanatory power. As a guideline, R^2 values of 0.75, 0.50 and 0.25 can be considered substantial, moderate and weak.

As shown in Table 4, the conceptual model with the specified constructs exhibits high R^2 values, indicating that the constructs are well explained and that the model demonstrates strong statistical power.

Table 4: R-Squared

Outcome	R2	Adjusted R2
Q7	0.619	0.619
Q12	0.745	0.744
Q14	0.677	0.676
Q18	0.692	0.692
Q19	0.670	0.669

Construct reliability was assessed using three standard indicators commonly applied in PLS-SEM: Cronbach's alpha, composite reliability (Jöreskog's rho), and Dijkstra–Henseler's rho (ρ_A). These measures are widely recommended in PLS-SEM literature for evaluating the reliability of latent constructs. As shown in

Table 5, all constructs exhibit high reliability values within the reported ranges: Cronbach's $\alpha \approx 0.88$ – 0.94 , Jöreskog's $\rho \approx 0.88$ – 0.94 a Dijkstra-Henseler's $\rho \approx 0.89$ – 0.95 .

Table 5: Reliability Measures

Latent	Cronbach's α	Jöreskog's ρ	Dijkstra-Henseler's ρ
Q8	0.910	0.913	0.919
Q11	0.927	0.926	0.927
Q13	0.868	0.868	0.869
Q16	0.895	0.896	0.897
Q7	0.918	0.916	0.923
Q12	0.929	0.928	0.930
Q14	0.861	0.859	0.863
Q18	0.824	0.825	0.826
Q19	0.914	0.914	0.914

All reliability coefficients exceed the recommended minimum threshold of 0.70 by a substantial margin, confirming a high level of internal consistency across the individual constructs. This indicates that the items associated with each latent construct exhibit strong internal coherence and reliably measure the same underlying concept. As the composite reliability values fall within the recommended range of 0.70–0.95, no construct shows indications of overreliability or item redundancy. Overall, the measurement model demonstrates very good reliability, and the constructs are operationalized in a consistent and robust manner. Here are partial regression submodels (designed at the beginning by the relations between latent variables). The estimates show the tendency of the relations (positive/negative). All p-values are less than 0.05; therefore, the model relations are accepted. The relations between composed latent variables are regressively significant.

Factor loadings represent standardized coefficients that express the strength of the relationship between an indicator and its latent variable. Higher loading values indicate that an indicator more accurately represents the underlying construct, whereas lower values suggest a weaker association and potential inadequacy of the item for measuring the construct. The loadings of individual indicators were used to assess the quality of the measurement model and to verify whether the items adequately represent their respective latent constructs. In line with methodological recommendations (e.g., Hair et al., 2022), loadings of at least 0.70 are considered adequate, while values in the range of 0.40–0.70 may be accepted provided that other indicators of construct validity meet the required thresholds. Indicators with factor loadings below 0.40 are generally regarded as insufficiently representative and should be considered for removal from the model. In the examined model, the majority of indicators reach the recommended values, confirming their strong association with the corresponding latent constructs and supporting the convergent validity of the measurement model. Lower factor loadings identified for a limited number of items indicate the potential need for their revision or exclusion in future analyses.

In the model, most items exhibit loadings between 0.60 and 0.85, which can be considered very good. A small number of items show loadings around 0.30–0.40 (e.g., selected items within Q7 and Q8). These values are still acceptable for the current model, particularly given the exploratory nature of the analysis.

The correlation matrix (Table 6) indicates that the latent constructs are strongly and positively correlated. The strongest relationships are observed among constructs Q12, Q11, Q13, and Q14 ($r = 0.82$ – 0.89), which jointly represent closely related aspects of the examined phenomenon. Correlations among the remaining constructs (e.g., Q7 and Q8) range from moderate to high, suggesting a strong theoretical linkage between them. Importantly, none of the correlation coefficients exceeds the threshold of 0.90, indicating the absence of excessive redundancy among the constructs. Overall, the correlation matrix supports the theoretical coherence of the model and suggests the presence of well-defined, interrelated latent variables.

Table 6: Observed construct correlation matrix

	Q8	Q11	Q13	Q16	Q7	Q12
Q11	0.748					
Q13	0.726	0.849				
Q16	0.705	0.736	0.747			

Q7	0.787	0.765	0.667	0.724		
Q12	0.697	0.863	0.779	0.803	0.755	
Q14	0.704	0.830	0.823	0.852	0.749	0.887
Q18	0.618	0.662	0.668	0.832	0.672	0.783
Q19	0.659	0.733	0.692	0.818	0.727	0.773

As part of the model evaluation, the directional relationships between latent constructs were analysed using standardized regression coefficients (path coefficients). These coefficients quantify the strength and direction of the effect of one latent variable on another and serve to test the formulated hypotheses. The values of path coefficients typically range from -1 to 1 , with higher absolute values indicating stronger effects. The statistical significance of individual relationships was assessed using p -values. In line with methodological recommendations (Hair et al., 2022), relationships with $p < 0.05$ are considered statistically significant.

In the analysed model, several relationships proved to be both strong and statistically significant, most notably the paths $Q8 \rightarrow Q7$, $Q11 \rightarrow Q12$, $Q13 \rightarrow Q14$, and $Q16 \rightarrow Q18$ and $Q19$. These results confirm the key role of these constructs in predicting the respective outcomes. Overall, the findings indicate that the structural model exhibits well-defined and theoretically meaningful relationships among the key latent constructs. The model thus provides empirical support for hypotheses H1–H4, confirming the relevance of managerial competencies, technological infrastructure, process integration, and performance monitoring for digital transformation in transport enterprises.

A summary of the hypothesis testing results is presented in Table 7.

Table 7: Evaluation of hypotheses

Hypothesis	Relationship	β (path coefficient)	p-value	f^2	Result
H1	$Q8 \rightarrow Q7$	0.603	< 0.001	0.336	Accepted
H2	$Q11 \rightarrow Q12$	0.661	< 0.001	0.711	Accepted
H3	$Q13 \rightarrow Q14$	0.795	< 0.001	1.959	Accepted
H4a	$Q16 \rightarrow Q18$	0.637	< 0.001	0.810	Accepted
H4b	$Q16 \rightarrow Q19$	0.479	< 0.001	0.251	Accepted

Discussion

The results of the structural model confirm that managerial digital competencies have a statistically significant and practically relevant effect on the extent to which software and hardware technologies are utilized in transport enterprises. This finding is consistent with prior studies by Ubiparipovic et al. (2022) and Kaganer, E., Gregory, R. W., & Sarker, S. (2023), which emphasise that management's ability to understand digital technologies and strategically govern their use represents a key prerequisite for successful digital transformation. In contrast to studies primarily focused on technological investments (e.g., Luo et al., 2025), the findings of the present study indicate that technological resources alone, without adequate managerial competencies, do not lead to higher levels of digital maturity.

The importance of process integration identified in this study represents one of the most substantial contributions of the empirical analysis. The finding that process integration is among the strongest predictors of actual digital transformation corroborates the conclusions of Mutlu et al. (2022) and Kraus and Marchenko (2021), who argue that the digitalization of isolated processes does not generate long-term value. In the context of transport enterprises, this effect is even more pronounced, as operational processes are highly interconnected and strongly dependent on real-time data (Durand et al., 2023).

From a methodological perspective, the achieved coefficients of determination (R^2) can be considered satisfactory to high given the predictive orientation of the research, in line with methodological recommendations (Hair et al., 2019, Lazur, J., Hynek, J., & Hruska, T., 2024). At the same time, the results suggest that a portion of the variance in digital transformation remains unexplained, which opens avenues for further research incorporating additional factors, such as institutional or cultural influences.

Another noteworthy finding concerns the significance of monitoring performance metrics related to digital transformation and cybersecurity. This result extends the existing literature, which often addresses these areas separately (Luo, T., Qu, J., & Cheng, S., 2025; Wang & Wang, 2023). The study suggests that, in the transport sector, performance management and security constitute integral components of digital transformation rather

than merely supportive activities. Compared with previous studies focusing predominantly on manufacturing firms or generic models of digital transformation (Luo et al., 2025; Szopa & Cyplik, 2020), this study offers a sector-specific perspective that explicitly accounts for the regulatory, operational, and safety-related characteristics of transport. In doing so, it responds to calls in the literature for contextually grounded empirical models of digital transformation.

Implications for Policy Making and Governance

The results of this study indicate that the effectiveness of digital transformation in transport enterprises depends not only on technological availability, but crucially on managerial digital competencies, process integration, and performance management. Consequently, public policies focusing primarily on technological subsidies or infrastructure investments are insufficient. National governments and regulators should complement such measures with initiatives aimed at strengthening managerial and organizational capabilities, including sector-specific executive education, training programs in digital leadership, and the dissemination of best practices in digital transformation management.

Furthermore, the strong role of process integration highlights the importance of regulatory frameworks that promote interoperability, data sharing, and harmonized digital standards across the transport sector. In highly interconnected regions such as Central Europe, coordinated governance supporting cross-border digital compatibility can significantly enhance sector-wide efficiency and resilience. Finally, policy makers should encourage the systematic monitoring of digital performance and cybersecurity through sector-relevant indicators integrated into regulatory reporting or public procurement criteria.

Practical implications for companies

For transport enterprises, the findings demonstrate that digital transformation should be approached primarily as a strategic and organizational challenge rather than a purely technological one. Companies should prioritize the development of managerial digital competencies, enabling leaders to align digital initiatives with business objectives and manage organizational change effectively.

In addition, firms should focus on the integration of core operational processes rather than on the digitalization of isolated functions. A process-oriented approach enhances transparency, reduces fragmentation, and increases the scalability of digital solutions. Finally, systematic performance measurement and cybersecurity management should be embedded into digital transformation strategies from the outset, as they are essential for achieving sustainable and resilient transformation outcomes.

Conclusions

This article focused on the analysis of the key determinants of digital transformation in the transport sector, with particular emphasis on managerial digital competencies, technological infrastructure, process integration, and the measurement and management of digital performance. The aim of the study was to contribute to a deeper understanding of the mechanisms underlying digital transformation in an industry characterised by high operational complexity, strong regulatory pressures, and dependence on real-time data.

The findings indicate that achieving actual digital transformation in transport enterprises is primarily driven by managerial digital competencies and the ability to integrate digital technologies into business processes. Particular importance was confirmed for process integration, which emerged as one of the strongest predictors of digital maturity.

From a theoretical perspective, the study contributes to literature by empirically confirming the relevance of an integrated approach that combines managerial competencies, technological infrastructure, and process integration. From a practical perspective, the results offer important implications for the management of transport enterprises. Investments in digital technologies should be accompanied by targeted development of digital competencies among managers and employees, support for process integration, and the implementation of relevant performance indicators. Managers should perceive digital transformation as a long-term strategic process rather than as a set of isolated technological projects.

Despite its valuable contributions, the study has several limitations that should be considered when interpreting the findings. The empirical analysis is based on survey data and perceptual measures, which may be subject to respondents' subjective assessments. Another limitation relates to the size and structure of the research sample, which may constrain the generalizability of the results to the entire transport sector or to other national contexts. In addition, the study relies on cross-sectional data, which does not allow for capturing the dynamic nature of digital transformation over time.

Based on the identified limitations, several directions for future research can be proposed. Further studies could focus on longitudinal analyses tracking the development of digital transformation in transport enterprises over longer time horizons. It would also be valuable to extend the research model by incorporating institutional, cultural, or environmental factors and to apply it in an international comparative context. Future research could

further explore the role of different employee groups, particularly operational staff, as well as conduct a more in-depth examination of the relationship between digital transformation and sustainability in the transport sector.

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